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Management from the Nova School of Business and Economics.

SMART CIRCULARITY: EXPLORING THE IMPACT OF ARTIFICIAL
INTELLIGENCE ON THE CIRCULAR ECONOMY

BUILDING BLOCK C: CROSS-SECTOR COLLABORATION

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This study delves into the transformative role of artificial intelligence (AI) in the circular economy (CE), focusing on circular product design, circular business models, and cross-sector collaboration (C-SC). Highlighting CE as a sustainable alternative, the research crafts a conceptual framework showcasing AI's positive impact on these building blocks. It provides guidance for stakeholders transitioning to a CE, emphasizing AI's role in fostering innovation and efficiency. By addressing barriers to C-SC, the study underscores AI's essential role in facilitating collaborative practices across sectors, laying the groundwork for future research and practical use cases to smooth the transition to a circular economy.

Keywords: *Artificial Intelligence, Circular Economy, Digital Transformation, Circular Product Design, Product Integrity, Circular Business Models, Circular Advantage, Cross-Sector Collaboration, Collaboration Barriers.*

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1 Introduction

Today's society is dominated by consumption (Goodwin et al. 2019). Global waste production is projected to increase to 2.59 billion tons by 2030 and 3.40 billion tons by 2050 (Suchek et al. 2021). Hence, the 2030 Agenda for Sustainable Development published by the United Nations (2015) highlights the need for action towards more sustainable and thoughtful business practices. Especially in the European Union (EU), regulations are being tightened, placing an increased pressure on businesses to incorporate sustainability practices (European Commission n.d.). To effectively promote sustainability in the future, two different megatrends become increasingly important: Artificial Intelligence (AI) and the Circular Economy (CE) (Walker et al. 2020). Especially the symbiosis of these two megatrends is considered essential to ensure an effective transition from a linear economy to a CE (Ellen MacArthur Foundation 2019). To realize this transition a firm's entire value chain will be affected, whether by adopting existing processes or introducing new ones. According to the Ellen MacArthur Foundation (2011) these value chain activities can be divided into four building blocks (product design, business models, reverse cycle skills and cross-cycle & cross-sector collaboration), representing the different phases that companies should consider when committing to a CE. Thus, the primary focus of this research paper lies in examining these foundational building blocks and exploring the potential impact of AI on each of them. Consequently, the general research question reads as follows:

RQ1: What is the impact of AI on the circular economy building blocks: Product Design, Business Models and Cross-sector Collaboration?

The first building block concerns the product adjustments that companies need to make when incorporating circular ideas in the design phase. The potential of AI to support this transition is promising. However, the specific cases in how AI can support circular design need to be further explored. Therefore, the first research question reads as follows:

RQ1a: How can AI applications be strategically integrated into the design process to preserve the integrity of tangible products?

The second research question examines two building blocks —specifically, the second and the third. The second building block refers to business models and the necessary adjustments required to promote CE practices. In parallel, the third building block centers on reverse logistics, which can be regarded as a sub-topic, representing a distinctive operational approach within business models fostering circular principles. Therefore, the second research question asks:

RQ1b: How can businesses strategically integrate AI along their value chain to enhance circular business models and create a ‘circular advantage’ in the context of resource efficiency, waste reduction, and product longevity?

Finally, the third building block, cross-sector collaboration, concerns the necessary interaction between sectors to develop CE initiatives. Transparency and open communication is needed to exchange information on product materials. However, there are serious barriers that hinder effective cross-sector collaboration. Considering this, the third research question is expressed as follows:

RQ1c: How can AI help overcome the current challenges of effective cross-sector collaboration in a circular economy?

To shed light on the above-mentioned research questions the paper is structured in the following way. First, the literature review provides an overview of the current research landscape on CE, AI, and the intersection of both topics. Second, the fundamentals of the three deep dive topics, which are based on the three building blocks, are outlined to establish a shared understanding. Third, before delving into the analysis, the methodology provides further insights into the structure of the research and the data collection process. Fourth, the paper includes an in-depth analysis for each building block, starting with the impact of AI on

circular product design, preceding with the role of AI in circular business models and ending with AI opportunities to foster circular cross-sector collaboration. Succeeding the deep dives, a comprehensive discussion integrates the findings of the three distinct parts and answers the general research question with the help of a newly developed framework. Sixth, the paper outlines theoretical and managerial implications directed towards scholars and stakeholders involved in the CE, and society at large. The study concludes by indicating the research limitations and suggesting potential avenues for future research.

2 Literature Review

2.1 The Circular Economy

2.1.1 Definition and Evolution of the Circular Economy

The prevailing linear economic model, which is based on the “take, make, dispose” paradigm, is characterized by the over-exploitation of finite materials and fossil fuels, which leads to a significant environmental impact (Ellen MacArthur Foundation 2019). The problem with a linear or, so called, cradle-to-grave economy is its dependence on continuous extraction and consumption, limiting sustainable growth (McDonough and Braungart 2007). As a result, there are growing calls for a paradigm shift to a CE that creates value rather than extracting it. The CE concept has gained momentum with increasing interest from businesses, governments, and academics worldwide (Ellen Mac Arthur Foundation 2019). For example, the Chinese government and the European Union have promoted the paradigm shift in recent years by incorporating CE principles in their future strategies (Prieto-Sandoval, Jaca, and Ormazabal 2018). In addition, other factors such as changing customer needs, resource scarcity and the opportunities of the fourth industrial revolution drive the emergence of a CE (PwC Hungary 2018). The CE proposes an alternative approach to the linear model, aiming to create a closed-loop system in which used resources and products are recovered and waste is minimized with the objective to decouple environmental impact from economic growth

(Prieto-Sandoval, Jaca, and Ormazabal 2018; Ghisellini, Cialani, and Ulgiati 2016). Due to the dynamic nature of the economic landscape, the term CE lacks a standardized definition. Kirchherr, Reike, and Hekkert (2017) attempt to articulate a comprehensive understanding of the concept of the CE based on an analysis of 119 distinct definitions. They ultimately define CE as “an economic system [...] that replace[s] the ‘end-of-life’ concept with the reduction, alternative reuse, recycling, and recovery of materials in production, distribution, and consumption processes, thus addressing the micro level (products, companies, consumers), the meso level (eco-industrial parks), and the macro level (city, region, nation, and beyond), with the goal of achieving sustainable development” (224). Complementing this definition are three fundamental principles integral to the concept of CE. As outlined by the Ellen MacArthur Foundation (2019), CE is grounded in the principles of “preventing waste and pollution, keeping products and materials at their highest value, and regenerating natural systems” (6).

According to Popović and Radivojević (2022), CE ultimately aims to extend the product life cycle by utilizing the 3Rs of *reducing, reusing, and recycling* materials, components, and products so that they can be repurposed as new inputs for another cycle. Ayres (1992) repeats two of the three Rs as two central resource loops to foster circularity: the reuse of goods and the recycling of materials. This is in line with the concept of slowing and closing the resource loop, mentioned by Bocken et al. (2016). Slowing resource loops involves designing for long and extended product life, contributing to an extended product utilization and hence a slowdown of the flow of resources. In contrast, closing resource loops focuses on recycling to achieve a circular flow of resources. McDonough and Braungart (2007) further distinguish between technical and biological cycles in which resource loops flow as seen in Appendix 1. On the one hand, the biological cycle refers to organic materials such as food or cotton that can return to the system through composting or digestion. On the other hand, the technical

cycle refers to a closed resource loop in which inorganic materials can stay in continued use through reuse, repair, remanufacturing, or recycling (Ellen MacArthur Foundation 2019).

2.1.2 Benefits

The adoption of a CE promises an array of distinct advantages. According to Sehnem et al. (2019), the projected outcomes include a 25% overall increase in material efficiency, a replacement of 50% of all new materials with secondary materials, and a doubling of the lifetimes of consumer durables. These projections underscore the CE potential for *resource conservation*, emphasizing the efficient use and reuse of materials. Second, by focusing on practices such as recycling, remanufacturing, and refurbishing, the CE stands out for its commitment to *waste reduction*, diverging from the wasteful habits of the traditional linear economy. For instance, Schroeder, Anggraeni, and Weber (2019) point out that there is great potential specifically for emerging industries such as Brazil and Mexico, which today focus primarily on landfilling. Third, *energy savings* are a notable benefit, as recycling and reusing materials generally demand less energy than extracting and processing new raw materials due to a reduction in production steps (Wijkman and Skånberg 2015). Moreover, Wijkman and Skånberg (2015) underscore that the CE not only reduces energy but has the potential to significantly decrease CO₂ emissions as well.

The CE is not only environmentally sound but also economically promising. It is positioned to stimulate *economic growth* by fostering new business opportunities, particularly in recycling, remanufacturing, and repair services (Ellen MacArthur Foundation 2019; Sehnem et al. 2019). Additionally other business opportunities, such as *forming networks* and partnerships within and across industries or sectors, are also gaining in importance (Kahn, Daddi, and Iraldo 2020). The shift towards circular business models is expected to generate *employment benefits* and spark innovation, contributing to a sectoral shift toward the service industry (Schroeder, Anggraeni, and Weber 2019). Furthermore, the CE presents tangible *cost*

savings for businesses through the reuse of materials, diminishing the need for new resource purchases (Ellen MacArthur Foundation, 2019). Thus, the CE emerges as a comprehensive and forward-thinking solution, addressing environmental concerns while bolstering economic resilience and efficiency.

2.1.3 Challenges

The statement that only about 6% of materials in the global economy are currently recycled highlights the early stages of the CE realization (Schroeder, Anggraeni, and Weber 2019,). It should be noted that, despite the growing interest in CE, the concept is still in its early stages. While economies grapple with the need to transition from a linear economy to a CE, many new challenges emerge for contemporary businesses, compelling them to reconsider established practices and models (Suchek et al. 2021). This is compounded by the underlying tension between economic growth and sustainable practices, necessitating a delicate balance in organizational strategies when working towards circularity (Hopkins et al. 2018). The study by Bressanelli, Perona, and Sacconi (2018) identifies 24 challenges clustered in 4 categories that heavily influence the transition from a linear to a circular business strategy. First, *economic and financial viability* represents a pivotal challenge, urging businesses to reconcile profit motives with the imperative of sustainability. Second, there are major *market and competition risks*, demanding adaptability in the face of evolving consumer expectations and a shift in market dynamics. Third, the *redesign of products* in alignment with the 3R principle introduces product characteristics as a critical challenge, requiring innovation and creativity in manufacturing processes (Ghisellini, Cialani, and Ulgiati 2016; Heshmati 2017). Last, *technological challenges* pose a substantial hurdle, necessitating advancements in waste management, recycling, and material recovery technologies. These challenges collectively represent a barrier to the smooth transition to a CE, compelling businesses to reassess their structures, strategies, and supply chain dynamics. In navigating this landscape, strategic levers

such as adjusted product design, the adoption of service-oriented business models, and the formation of partnerships along supply chains emerge as critical components for overcoming these challenges and achieving a sustainable and circular future.

2.2 Artificial Intelligence

2.2.1 Definition and Evolution of Artificial Intelligence

Past literature has presented numerous definitions of AI. Beginning in the mid-20th century, Alan Turing, a British logician, and computer scientist, was the first to conceptualize the term AI. In 1950, his Turing Test set the foundation for the theory and development of AI by asking the question: “Can machines think?” (Turing 1950, 433). This so called ‘imitation game’ aimed to assess a machine's ability to display human intelligence by examining whether the machine could hold a conversation with a human, without being recognized as artificial. To date, no computer has ever passed this test, hence Turing’s early conception of describing AI as “a machine that can learn from experience [...] with the possibility of letting the machine alter its own instructions” (Britannica n.d., under “Alan Turing and the beginning of AI”) holds till today. Shortly after, during the Dartmouth Summer Research Project in 1955, a diverse group of researchers contributed to the idea of ‘thinking machines’ in which they analyzed whether computers could engage in cognitive tasks like playing games or providing mathematical theorems. Thus, John McCarthy, one scientist from Dartmouth, described AI as “the science and engineering of making intelligent machines” (Management Solutions, n.d.). Marvin Minsky, another ‘founding father’ of AI, supported that by explaining AI as “the science of making machines do things that would require intelligence if done by men” (Woodford 2021). Moreover, in more recent literature, the definitions of AI have developed based on its technological advancement over the years. For instance, Russell and Norvig (2016) refer to an AI as a computational system that can mimic cognitive human functions such as learning, decision making and problem solving. Later, Zhang and Lu (2021) defined

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AI as “a multidisciplinary technology, one with the capability of integrating cognition, machine learning, emotion recognition, human-computer interaction, data storage, and decision-making” (1).

Next, the analysis conducted by Taherdoost and Madanchian (2023) gives a more detailed description on how these systems work and explains that AI is a knowledge-driven project that involves acquiring and analyzing knowledge, studying its expression methods, and employing these approaches to achieve the effect of replicating human intellectual activities. To achieve this, the technology consists of six key components to enable such imitation, which are listed and explained in Appendix 2. Additionally, due to the strong adoption of the technology in the last years, scientists have classified different types of AI based on its capabilities - artificial narrow intelligence (ANI) and artificial general intelligence (AGI). ANI, often referred to as weak AI, focuses on models which are trained to perform one task extremely well, even better than humans (Flowers n.d.). These singular tasks can be realized by AI technologies, mostly algorithms which we are able to use in today's world, for instance facial recognition software, voice assistants, recommendation engines or self-driving cars. One major sub-type is generative AI, which helps to generate new content with its most pressing example of ChatGPT. AGI, also known as strong or deep AI, is still a theoretical form of AI and only seen in science-fiction movies (e.g., Star Wars's R2-D2 or Wal-E) (Flowers n.d.). Wayne Chang, co-founder of Digits, defined it as the following: “however, the speed of innovation towards AGI is accelerating. In its ideal state, AGI would perform tasks that are identical to or surpass those that a human would perform” (Betz 2022). This indicates that AGI will be self-aware and capable of performing sophisticated cognitive processes such as thinking, contextual understanding, and will have the capacity for emotional expressions (Flowers n.d.). Some researchers have proposed a third type of AI – artificial super intelligence (ASI). This hypothetical concept claims that AI can surpass and emulate human

intelligence in everything we do. By deploying a greater memory and fast data processing this type would grant it superior abilities in scientific creativity, general wisdom, and social skills (Müller and Bostrom n.d.).

2.2.2 Benefits

The existing body of literature underlines several advantages associated with AI implementation. Insights from the 2017 State of Cognitive Survey from Deloitte, involving 250 executives, reveals that AI holds the potential to optimize business processes and workflows (Davenport 2018). These optimizations can include AI algorithms that analyze historical data to provide reliable demand forecasts, AI-based systems that track inventory levels or AI-powered sensors allowing predictive maintenance in terms of prognosticating equipment errors before they occur (Nadimpalli 2017; Wamba et al. 2021). All these result in higher efficiency and effectiveness, leading to increased business productivity (Davenport 2018; Nadimpalli 2017; Ransbotham 2021). Additionally, AI technologies can enhance decision-making processes by handling massive amounts of data in a time efficient way. For instance, predictive analytics are commonly used for marketing activities, as AI algorithms can use historical data to forecast customer behavior to adjust campaigns accordingly (Verma et al. 2021). Another example frequently found is the use of AI for pattern recognition in medical data to assist doctors to diagnose diseases (Lee, Bubeck, and Petro 2023). Moreover, the implementation of AI yields positive side effects, such as the optimal utilization of human resources. By leveraging AI capabilities, staffing levels can be reduced while collaboration is enhanced, enabling scarce expertise to be directed toward more strategic and creative activities (Balakrishnan et al. 2020; Davenport 2018; Ransbotham 2021).

2.2.3 Challenges

In reviewing the existing literature, it becomes apparent that while AI promises transformative potential, numerous challenges obstruct its seamless integration into business environments.

Schmitt (2023) highlights the limitation of a lack of robust digital infrastructure hindering digital transformation. Davenport (2018) and Kraus et al. (2021) stress the importance of a clear digital strategy and mature systems for successful AI implementation. Another challenge also stems from a shortage of skilled labor, as emphasized by Kraus et al. (2021), with inadequate training programs exacerbating the issue (Davenport 2018; Ransbotham 2021). In addition, managerial unfamiliarity, and employee resistance, particularly among data scientists, are obstacles requiring active change management strategies (Balakrishnan et al. 2020; Kraus et al. 2021). Next to these implementation challenges, some literature suggests that the application itself comes with concerns. One lies in the lack of transparency of many AI algorithms as these systems are often considered as ‘black boxes’, unable to understand how these arrive at a specific outcome (Adadi and Berrada, 2018). Subsequent, Ntoutsis et al. (2020) highlight that AI is not yet self-contained, indicating these systems can take on and maintain biases present today when designed without considering any fairness criteria. To conclude, the perspective of experts such as Stephen Hawking stating that “the development of full Artificial Intelligence could spell the end of the human race” (Clark 2017), and Bill Gates expressing that humans should be worried about the threat posed by AI (Rawlinson 2015) show that it is crucial for society to enable a co-existence with AI along ethical guidelines and responsible governance.

2.3 Artificial Intelligence in the Circular Economy

2.3.1 Increasing Role of Artificial Intelligence in the Circular Economy

In recent years, literature bridging AI and the CE has surged, signifying its heightened importance and currency in academic discourse. Agrawal et al. (2021) found a significant upswing in research activity from 2007 until today. This increasing scholarly interest underscores the growing acknowledgment of AI’s pivotal role in advancing CE. According to Chauhan, Parida, and Dhir (2022) research in this domain is fragmented across

interdisciplinary fields and scattered across a multitude of journals, methodologies, and themes. Moreover, AI and CE have not only garnered significant attention from academics but also from practitioners, policymakers, and corporations worldwide (Kortelainen et al. 2018).

2.3.2 Benefits

Most scholars found that AI-based technologies contribute to an optimized use of resources and energy, improved recycling processes, and an increased state of sustainability for circular products. Consequently, the discovery made by Abdelhafeez and Ramakrishna (2021) validates the previously mentioned assertion, indicating that the integration of AI in the CE holds the capacity to revolutionize existing linear systems of production and consumption, resulting in more sustainable models. However, it is important to acknowledge that AI does not function in a vacuum; AI systems are typically developed and deployed in tandem with other digital technologies (Roberts et al. 2022). As an illustration, the integration of the Internet of Things (IoT) and AI was examined by Kannan et al. (2023), showcasing a compelling application in smart waste management. By utilizing IoT sensors, data on waste quantities is gathered, subsequently fed into AI algorithms to optimize the overall efficiency of the waste management process. Another example, mentioned by Özdemir et al. (2021), underscores how AI-powered technology can revolutionize recycling through automated sorting and efficient material separation, contributing to cost reductions. Thus, there is a resounding consensus in the academic literature - a consensus that proclaims AI as a facilitator of CE, specifically in waste management and recycling. The profound resonance of this perspective is illustrated by the insights from various other studies. Agrawal et al. (2021) emphasize that AI stands as a potent tool to expedite the transformation from the linear economy to the CE paradigm. Notably, the fusion of AI with CE principles serves as an exciting catalyst for innovation and sustainable development (George, Merrill, and

Schillebeeckx 2020). The study by the Ellen MacArthur Foundation (2019) reinforces this narrative, highlighting that AI can enhance CE innovation across industries, offering remarkable advancements in product design, business model innovation, and cross-sector collaboration – an essential focus for this research paper. In summary, current research delves into the overall impact of AI on the CE, incorporating AI-based use cases, with a notable emphasis on recycling activities. However, a distinct scarcity persists in the literature regarding specific AI applications in other areas aligned with CE principles.

2.3.3 Challenges

While numerous academic studies have predominantly highlighted the immense potential of AI in catalyzing the transition towards CE, it is equally imperative to scrutinize the potential challenges and ethical dilemmas associated with the integration of AI technologies in the CE. First, unsustainable technologies pose environmental risks as they increase energy consumption and generate electronic waste. For instance, digital devices, digital infrastructures and the sheer number of digital data centers necessary to store the data required for AI systems require significant computing power and thus consume enormous amounts of energy. (Berg et al. 2020; Kouhizadeh, Sarkis, and Zhu 2019). Second, AI can further promote linear consumption patterns, which contradicts the ideals of the CE. A notable concern arises in the context of digitally enabled commerce, where AI can lead to increased consumption, creating a surge in demand for transportation and packaging. This surge exacerbates the environmental impact of unsustainable practices, thereby posing a significant obstacle to the principles of the CE (Berg et al. 2020). Third, data privacy concerns arise as AI processes sensitive information, risking consumer trust (Roberts et al. 2022). This raises questions about who has access to customer data, how it is being used, and whether it is adequately protected against misuse and breaches (Roberts et al. 2022). Last, AI adoption may exacerbate economic inequality, concentrating high-skilled jobs in digital services (Lawrence, Roberts, and King

2017; Muro 2020). Balancing AI's benefits with these risks is essential for a responsible and sustainable integration into the CE.

3 Research Outline

In the pursuit of comprehensively understanding the transformative influence of AI on the CE, the research paper delves into a detailed examination of the three distinct research questions on A) Product Design, B) Circular Business Models, and C) Cross-Sector Collaboration. Together, these elements address the overarching research question. The relationship of individual parts and one outcome is illustrated in Figure 2.

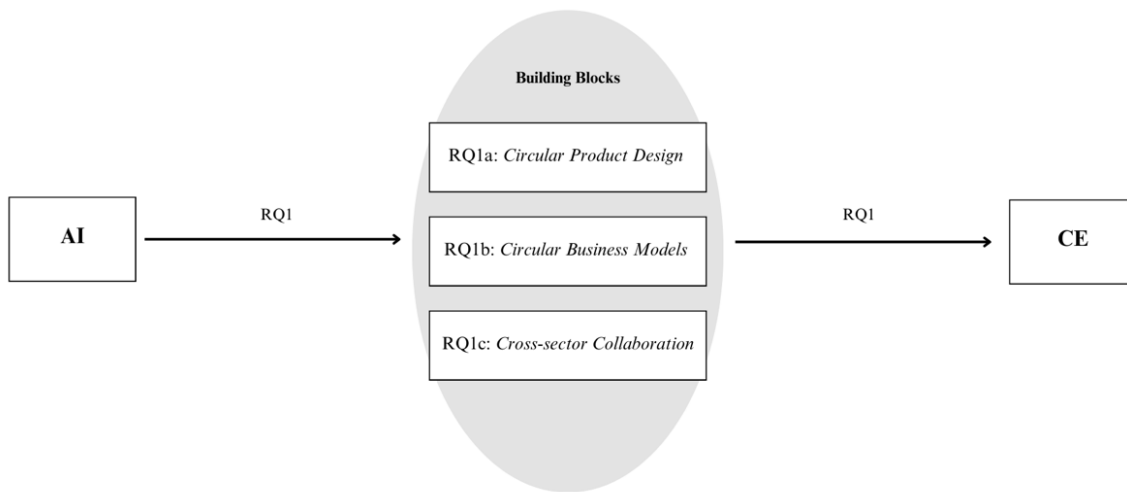


Figure 1. Comprehensive research model (Source: Own illustration)

The subsequent sections will explore the effect within each domain, unraveling the ways in which AI shapes circular product design strategies, optimizes business models for circular practices, and fosters effective cross-sector collaboration. By scrutinizing these individual facets, it is aimed to gather profound insights into the multifaceted impact of AI on the CE, ultimately contributing to a holistic understanding of these building blocks.

4 Methodology

4.1 Research Design

This study is driven by the central research question: *What is the impact of AI on the CE Building Blocks: Product Design, Business Models and Cross-Sector Collaboration*. To address this inquiry, a qualitative research design was used, combining a comprehensive literature review with semi-structured expert interviews for all three sub-topics. The individual literature reviews on each topic establish a foundational understanding of the dynamics between AI and CE within a specific building block, offering insights into historical developments and key findings over time. Subsequently, semi-structured expert interviews provide a real-time exploration of this AI-CE intersection, allowing to capture contemporary perspectives from experts in this field. This two-fold approach ensures a holistic investigation into the multifaceted relationship between AI and CE.

4.2 Participants

The selection of interview participants is a critical component that shapes the depth and breadth of our insights. Six experts were carefully selected based on their expertise in CE, AI, or the intersection of both domains. These interview partners work in different industries, companies, and positions, which ensures diverse perspectives on AI and CE. Participants were recruited through a combination of personal networks and their recommendations as well as targeted outreach via LinkedIn. No specific sampling methods were employed. Throughout the analysis, participants were anonymized, hence only initials are used while presenting the respective research findings. A detailed overview of the experts that have been interviewed is provided in Appendix 3.

4.3 Data Collection

The data collection process involves a sequential application of a literature review and semi-structured expert interviews. The literature review serves as the initial step, providing a

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comprehensive understanding of AI and CE and guiding the subsequent interviews by offering a contextual background on each of the three building blocks. Subsequently, a total of six semi-structured expert interviews were conducted from November 7 to November 17 in 2023. The interviews lasted for 45-60 minutes in total and were facilitated through video calls on MS Teams. Each researcher was allocated 15-20 minutes to discuss their individual sub-topic with each interviewee. Prior to the interviews, explicit consent was obtained for recording and transcription, which was then carried out with MS Teams during the interviews (see interview transcripts in Appendix D). Leveraging the concept of semi-structured interviews, the researchers employed a predetermined set of open-ended questions while retaining the flexibility to delve into additional topics based on the expert's responses. This approach, highlighted by Adeoye-Olatunde and Olenik (2021), allows focused interviews while providing autonomy for exploring pertinent ideas that may arise, fostering a comprehensive and adaptable exploration of the subject matter.

4.4 Data Analysis

The data analysis procedure uses a qualitative content analysis approach, complemented by manual techniques. Drawing inspiration from Thompson's (2002) emphasis on the human touch in data analysis, this study embraces a manual approach, involving physical interactions with the data, such as highlighting text and manually merging similar themes across different interview transcripts. Combining a hands-on approach with qualitative content analysis enables a systematic examination and coding of expert responses, revealing recurring patterns and underlying meanings within the data, thereby offering a comprehensive understanding of the impact of AI on the CE (Thompson 2002).

5 Building Block A: Circular Product Design – Annelie Sophie Steinbrenner

6 Building Block B: Circular Business Models – Lena Maria Pertz

7 Building Block C: Cross-Sector Collaboration – Lena Sophie Thielmann

7.1 Introduction

When considering the two megatrends CE and AI, the question arises how a possible interaction between these two might look like. In order for an organization to embrace these trends a new mindset is needed to adapt an organization's entire infrastructure and find AI interfaces. However, this transition can hardly be managed by companies alone. Close collaboration across the entire value chain and beyond is required to gather all information needed and develop towards circularity (Ellen MacArthur Foundation 2019). The spectrum of different forms of collaboration ranges from simple business transactions to full network formations (Majava, Isoherranen, and Kess 2013). Collaboration, especially cross-sector collaboration (C-SC), in the CE is widely discussed as a central building block but has not yet been fully analyzed (Elia, Gnoni, and Tornese 2017; Ellen MacArthur Foundation 2011). While existing literature has identified various challenges for C-SC, none has provided an overview of the differences in their importance and relevance, as well as the opportunity for AI applications as a specific strategy to address them (Luthra et al. 2022), representing a significant gap in the literature. This gap spells the motivation for answering the following research question: *How can AI help overcome the current challenges of effective cross-sector collaboration in a circular economy?*

This study aims to assess the importance of addressing the challenges C-SC is facing in the CE and the potential impact of AI in overcoming them. The research is organized as follows: First, a literature review is conducted to examine current research on C-SC in the CE and the use of AI applications in these areas. Second, the research methodology will be described in detail, followed by the presentation of the findings. These aspects will be examined in the final framework and therefore the fourth section contains the discussion. Finally, implications, limitations and possibilities for future research will be presented.

7.2 Literature Review

7.2.1 Different Forms of Collaboration and the Importance of Cross-Sector Collaboration

Majava, Isoherranen, and Kess (2013) emphasize the wide variety of different business collaborations ranging from simple business networks (the interaction between companies or business units) to business ecosystems and innovation hubs (relating to multi-stakeholder interaction). The various forms of collaborations and their characteristics reflects how the field spreads. Cisi et al. (2018) point out the advantages that collaborations and networks offer. Firstly, *established trust* reduces transaction costs between participants due to aligned goals and the duration of the collaboration. Secondly, *economies of scale* can lead to resources being shared more easily. Lastly, *information sharing* within networks is encouraged, leading to higher operational efficiency and technological improvements through increased innovation (Cisi et al. 2018; McQuaid 2010). Hence, interaction with various stakeholders is essential to maintain competitiveness and achieve long-term growth (Stiles 1995). For it to thrive, organizations must carefully assess which form of collaboration aligns best with their strategic objectives (Pisano and Verganti 2008). An important criterion is the relevance for today's industry dynamics. Becker and Smith (2018) point out that today's challenges such as health care or environmental issues require action by several stakeholders. To be able to incorporate such diverse stakeholders and simultaneously be adaptive to the dynamics of present challenges, the term cross-sector collaboration (C-SC) comes into play. C-SC includes "alliances of individuals and organizations from the nonprofit, government, philanthropic, and business sectors that use their diverse perspectives and resources to jointly solve a societal problem and achieve a shared goal" (Becker and Smith 2018, 2). Bryson, Crosby, and Stone (2015) emphasize four positive attributes of C-SC. The diverse structure of C-SC fosters the creation of public value which combines the characteristics of various sectors to maximize outcomes and compensate for weaknesses (Benington and Moore 2011). Additionally,

immediate, intermediate, and long-term effects can be observed. Immediate effects arise from the collaboration directly, such as “social, intellectual and political capital” (Bryson, Crosby, and Stone 2015, 656). Intermediate effects include amongst others new partnerships or joint actions that result from the collaboration. Finally long-term effects concentrate on the future success of the collaboration by including new partnerships or co-evolutions. It is important to note that companies are more likely to cooperate when they cannot achieve their objectives without cooperation, i.e., the immediate, medium-term, and long-term effects must outweigh an organization’s internal capabilities (Bryson, Crosby, and Stone 2006). Another positive outcome of C-SC is resilience and reassessment. Adapting collaborations through learning appears to be a key component of effective collaboration. Managing responsibilities within C-SC effectively is also an essential part of reducing complexity among collaborators, depicting an essential backbone of the collaborative framework (Bryson, Crosby, and Stone 2015). Bryson, Crosby, and Stone (2006) also emphasize the different challenges C-SC brings. Various stakeholders pursue diverse goals and are inclined to express their objectives differently, necessitating more upfront negotiation. Therefore, it is important to mention that different institutions and sectors follow different logics which are complex to align (Bryson, Crosby, and Stone 2006). Moreover, power imbalances among the collaborator’s present significant obstacles to the accomplishment of a successful C-SC, representing a source of mistrust and hinder effective interaction (Essabbar, Zrikem, and Zolgadri 2016). Bates (2013) also emphasizes the importance of a common language for successful C-SC, by addressing the points by Bryson, Crosby, and Stone (2006).

7.2.2 Cross-Sector Collaboration in the Circular Economy

In their study, Kahn, Daddi, and Iraldo (2020) discovered the necessity of collaborating with various partners, such as universities, suppliers, and business partners, as an integral part of the CE which are all found to be included in C-SC (Becker and Smith 2018). Hazen et al.

(2020) explain five strategies needed to create effective circularity (Appendix C1). Additionally, Çetin, De Wolf, and Bocken (2021) have developed five core principles (regenerate, narrow, slow, close & collaborate) and their corresponding development strategies for a CE, aligning with the strategies of Hazen et al. (2020). Upon further examination of these strategies, it becomes apparent that collaboration is incorporated into almost all the core principles of the CE. For instance, the core principle ‘regenerate’ includes the ‘exchange of surplus resources’ strategy, which, among other things, refers to the exchange of excess resources with local communities. Alternatively, ‘industrial symbiosis’ comes into play as a strategy for closing loops in the CE, referring to the interactivity of various industries for waste and by-product recovery. Finally, Çetin, De Wolf, and Bocken (2021) mention ‘collaboration’ as a core principle itself, including the two strategies: ‘support collaboration in the supply chain’ and ‘create knowledge and value networks’. PwC Hungary (2018) also highlights the concept of industrial symbiosis, which includes the two strategies mentioned by Çetin, De Wolf, and Bocken (2021), as it points out that “the waste of one industry can become the raw material of another” (14) and that this “can be achieved in an industrial park where companies are close to each other but can also encompass entire sectors (and geographical regions)” (14). Even though many benefits for C-SC have been found, there are still some barriers that need to be overcome for C-SC to be effective in the CE. Mallick et al. (2023) point out that the main obstacle to the implementation of the various CE principles is a lack of knowledge and experience hindering the strategy proposed by Çetin, De Wolf, and Bocken (2021). In their study, Luthra et al. (2022) found 27 different barriers to C-SC in a CE. These were divided into five categories: Operational Barriers, Contextual Barriers, Perceptual Barriers, Strategic and Management Barriers and Governance Barriers (Appendix C2), depicting an essential part of the research at hand.

7.2.3 Artificial Intelligence Opportunities for Cross-Sector Collaboration in the Circular Economy

For corporations, the potential of AI becomes increasingly promising, particularly in relation to the fourth industrial revolution, known as Industry 4.0 (Bai et al. 2020). In their study together with Google, the Ellen MacArthur Foundation emphasized the tremendous role AI can have in accelerating the transition towards the CE, pointing out that “exploring new ways to increase data accessibility and sharing will require new approaches and active collaboration between stakeholders” (Ellen MacArthur Foundation 2019, 33). Chui et al. (2018) stress the necessity for companies to consider various use cases to promote the growth of AI initiatives. Hence, their study identifies specific AI use cases with notable benefits, including predictive maintenance, logistics optimization, and customer service improvement. One critical limitation of AI highlighted by Chui et al. (2018) is the extensive data required, which can be a hindrance for some companies and Chui, Manyika, and Miremadi (2018) emphasize that AI tools must be tailored to the problem at hand to function properly. In a collaboration, these limitations could be eliminated due to the increased number of partners and the need for clear structures, as, for example, Mikhaylov, Estève, and Campion (2018) point out that AI is an essential component, especially in C-SC, promoting knowledge sharing through its tools and applications. In addition, Pishgar et al. (2021) stress the far-reaching benefits of AI in collaboration across different industries, e.g., around occupational health and safety. By pooling resources and expertise, the strengths of each sector are brought together, offering different business opportunities, an increased talent pool, network effects and an increased global perception (Demmerle n.d.). Marc (2023) also points out that collaboration is needed to promote the positive impact of AI, indicating a positive effect of collaboration on AI. Furthermore, AI and CE barriers related to lack of trust can be addressed through sufficient engagement in C-SC (Chui, Manyika, and Miremadi 2018b; Luthra et al. 2022; Demmerle

n.d.). Resulting, it can be concluded that a clear need for interaction between C-SC and AI exists. However, the specific opportunities for AI in C-SC are still to be discovered.

7.2.4 Development of Research Gap

As it is crucial to overcome barriers through new technological improvements and concepts, such as Industry 4.0 and, by extension, AI, which Tseng et al. (2018) describe as key to the necessary adoption of newer technologies for collaboration in the CE (Jan et al. 2023), the specific opportunities for AI are yet to be discovered. The established literature review of the different factors that are subject of this study, shows that the distinct opportunity for AI to overcome barriers of C-SC in the CE environment has not yet been discussed. Therefore, the focus going forward will be on the potential of AI to address current barriers to effective C-SC in the CE.

7.3 Methodology

To be able to answer the research question “*How can AI help overcome the current challenges of effective cross-sector collaboration in a circular economy?*“, two different types of data collection, a literature review, and semi-structured interviews, took place. These two approaches have been described in more detail in section 4: Methodology.

7.3.1 Research Design

For this academic paper, the initial analysis focused on the type of collaboration being evaluated. The literature review revealed that the most important form of partnership in a CE, is C-SC. Therefore, the interviews aimed to evaluate current barriers to C-SC in the CE and to explore how AI could offer solutions (Appendix C3). Thus, the study analyzes the aforementioned barriers by Luthra et al. (2022) in more detail. Based on the literature review, 27 C-SC barriers to CE were initially identified. However, according to Luthra et al. (2022), only 17 of the 27 identified barriers can be partially solved by Industry 4.0 technologies,

including AI applications (Jan et al. 2023). Hence, only those 17 technology relevant barriers were examined more closely (Appendix C4). As AI is a component, but not a synonym, of Industry 4.0, only barriers relevant to AI were selected for this research. To further detail only AI-related barriers, predictive maintenance, and deep learning use cases, which are core AI use cases identified by Chui et al. (2018a), were mapped against the 17 barriers. As a result, 10 ultimate barriers, primarily related to the use case of predictive maintenance and deep learning, were selected and categorized as AI-focus barriers. Since it mainly involves managing large amounts of data by analyzing it, identifying patterns and anomalies, and predicting or forecasting failures (Chui et al. 2018a), it can be considered as a key requirement for certain C-SC barriers.

The identified barriers from Luthra et al.'s (2022) research are: 1) *'Temporal dynamics of technology'* denoting the usage of diverse internal technologies by various collaborators. 2) *'Distinct operational and management practices'* signifies the differing planning approaches of individual sectors and stakeholders. The issue of conflicting monitoring amongst stakeholders for a company is a component of 3) *'Monitoring performance within multiple contexts'*. In addition, ensuring the security of data and the careful selection of data are critical obstacles that need to be overcome as part of barrier 4), which is the *'Risk of information loss'*. Alongside information loss, the importance of data quality serves as the primary rationale behind barrier 5) which is titled *'Lack of transparency and poor disclosures'*. Barrier 6), *'Misaligned interests of individuals across sectors'*, pertains to the distinct interests of the various participants in the collaboration. This demands overall performance measurement, which is currently lacking, and therefore barrier 7) *'Lack of standardization of performance management systems'* was identified. In addition, barrier 8), the *'Risk management approaches'*, arises from collaborators having their independent methods for identifying and mitigating risks. The penultimate obstacle, barrier 9), *'Poor demand/acceptance for*

environmentally superior technologies’ involves overcoming various stages and preferences of technologies in different countries for successful collaboration in the CE. Finally, *‘Inflexible policy and structure’*, barrier 10) obstruct companies from adjusting their processes to improve circularity and collaboration (Appendix C5).

7.3.2 Data Collection

The interviews were structured into three distinct parts guided by the previously described barriers. Initially, interviewees ranked the barriers according to their immediate importance for the CE, with the aim of identifying the most pressing barriers and later assessing whether they could be effectively addressed by AI. This led to the second stage of the interviews. After ranking the barriers importance, the interviewees were asked to identify which barriers have the greatest potential to be overcome with the help of AI applications. Following these two stages, a matrix was created (Appendix C6), which summarized the discussion for each interview. After, a comprehensive matrix was created based on the individual interviews, providing a final recommendation on which barriers need to be addressed immediately and where AI has the highest potential to support this transition.

7.4 Findings

The applied research methodology uncovered significant insights into the potential of AI to reduce barriers for C-SC in the CE. Six interviews were conducted, and the data collected was organized into six separate matrices, which can be found in Appendix C7. Based on the arguments presented in the interviews, a final matrix was created to illustrate the most pressing barriers for C-SC in the CE and the opportunity for AI to overcome them (Figure C1). It is important to note that all selected barriers were highly debated, and various arguments were presented. Therefore, the position of each barrier shown, is an agglomeration of the different arguments proposed, treated as a consolidation, and does not reflect a unanimous decision.

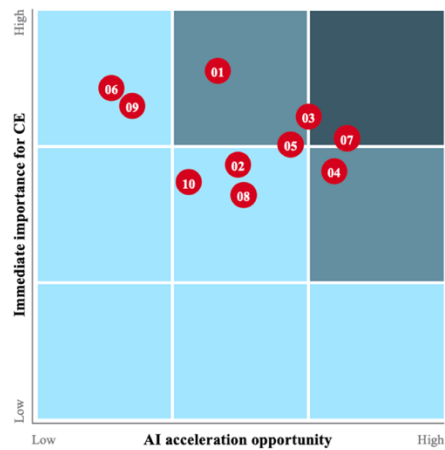


Figure C1. Consolidated Matrix empirically derived from expert interviews (Source: Own illustration)

7.4.1 Barrier Evaluation

In the following, the rationale behind the individual positioning of each barrier in the matrix presented in Figure C1 is explained, reflecting 1) its immediate importance for the CE and 2) the opportunities that AI applications have to overcome the respective barrier. Therefore, interviewee responses were derived from Appendix D.

Barrier 1) - Temporal dynamics of technology

The importance of barrier 1) for the CE was unanimously described as very significant and one of the most pressing. In the global supply chain, there are notable discrepancies in the existence and status of IT systems, particularly in developing countries where there may be a lack of system or internet connectivity as mentioned by MH. HK stresses that even in industrialized countries, technological systems remain at an insufficient level. As companies must, for example, openly communicate the individual components and origin of their products, the need for technological advancements is evident. Hence, the diverse technological stances pose the primary hurdle for C-SC in the CE. The interviewees also discussed the crucial role of AI in overcoming this barrier. While evaluating various statements, DK points towards the need to differentiate between the immediate and long-term

potential of AI in overcoming this barrier. As the main problem today is the lack of any technological systems among some partners, the first step should be on the digital integration of partners within a C-SC. Once a basic standard is established, AI has the potential to accelerate C-SC, especially in integrating different data systems and for data augmentation.

Barrier 2) - Distinct Operational and Management Practices

The study found that barrier 2) holds a lower degree of importance in its current role for CS-C. This is because it is seen as a general problem in the value chain and not a circularity-specific problem, being identified as a common issue among companies. Moreover, DK noted that modern partnerships involve specific steering committees consisting of key stakeholders, making it unnecessary for an entire company to participate. Nonetheless, TE, PdH and HK emphasize that AI applications have the potential to explain the varying practices by organizing unstructured data and harmonizing the differing practices to create synergies.

Barrier 3) - Monitoring performance within multiple contexts

Barrier 3) ranks in the upper third on the ‘immediate importance for CE’ axis, leading to sectors with different goals and incentives for engaging in C-SC. However, the barrier was not placed at the very top as PdH pointed out that many collaborations involve only two parties, making the barrier less significant in those cases. Shedding a light on the options AI has, to help overcome this barrier, several use cases proposed by MH, DK, TE and PdH were found. On the one hand, data collection, monitoring and controlling are use cases in which AI can play an essential role. On the other hand, contextualizing performance information for different target groups or different contexts is another important use case for AI which reflects the opportunities AI has in overcoming this barrier and aligning performance goals.

Barrier 4) - Risk of information loss

Examining barrier 4), it becomes apparent that the potential for AI in this scenario is greater than its immediate importance for C-SC in the CE. The role of information was extensively deliberated by the interviewees, resulting in various issues being embedded in this barrier. MH states that there is too much information to be processed and that the sectors lack an understanding on how to deal with data. Secondly, TE flags the insufficient availability of precise information, specifically with respect to stricter regulations. Nevertheless, it was unanimously agreed that having such information is crucial for C-SC in the CE. AI can play a vital role in overcoming this obstacle due to its numerous entry points. Particularly, generative AI was mentioned by PdH for its ability to act as a mediator in searching and CP pointed towards the filtering of available data for necessary information. DK added that many guidelines, including ISO Standards, specify the necessary information for companies. In such cases, AI can aid by storing required data.

Barrier 5) - Lack of transparency and low-quality disclosures

In the realm of information management, barrier 5) can be evaluated through two different dimensions. Evolving regulations such as the Corporate Sustainability Reporting Directive (CSRD) (Martinetti 2023) mentioned by DK, create increased pressure, especially on companies, to disclose very detailed information about their products. In collaborative efforts, MH emphasizes the need to balance mandated contractual information with a general openness to share. The latter has undergone a noticeable shift, with sectors becoming more open to sharing the necessary information pointed out by DK, therefore placing the barrier more towards a medium importance for CE. Nevertheless, PdH and HK note that a cultural barrier exists which constrains the free flow of information. During discussions regarding the potential for AI to improve this transition, Gaia-X and Catena-X (Gaia-X 2022; Catena-X n.d.) were highlighted by MH and DK as two examples of data sharing initiatives. AI can

potentially act as a facilitator between different sectors, collecting and distributing information to relevant stakeholders, thereby providing valuable support in the future.

Barrier 6) - Misaligned interests of individuals across sectors

In discussing barrier 6), it was agreed that it is very important for the CE. The diverse objectives of the various sectors involved in the collaboration undermine the ambition for circularity which was emphasized by CP, MH, DK, and HK. Despite the potential to prioritize general CE initiatives, HK points towards the lack of consensus on the definition of the CE which often leads to sectors pursuing conflicting goals. The only option for AI described by PdH is to comprehend how the various interests are possibly related by uncovering patterns in data. Otherwise, it was consistently described as a cultural problem that cannot be overcome using AI.

Barrier 7) - Absence of system standardization for performance management

Barrier 7) is found to be a fundamental challenge in pursuing C-SC as the alignment of goals is crucial in a partnership. CP states that various sectors have dissimilar comprehension of the required standards, and MH points towards the absence of data flows between the systems. These challenges are hindering sectors from entering collaborations in the currently developing CE. However, the potential impact of AI can assist in overcoming them. MH, DK and TE state that it is crucial to focus on translation, consolidation, and harmonization of data, along with the development of sharing platforms and governance concepts.

Barrier 8) - Risk management approaches

Barrier 8) was ranked the least important for the CE in the short term. MH mentions it is crucial to distinguish between the significance for cooperation and the handling of risks within the sectors. Therefore, it is considered to be of medium importance for CE, being mainly important within sectors, but not necessarily for collaboration. Nonetheless, HK stresses that forming collaborations in the CE has the potential to reduce risks in the long term, particularly

in local C-SCs, by avoiding global supply chain bottlenecks. CP, DK, and HK suggest that AI holds the potential to create risk assessment algorithms that increase transparency, thereby assuming the responsibility of risk assessment and calculation about possible decision outcomes.

Barrier 9) - Poor demand/acceptance for environmentally superior technologies

Barrier 9) poses a crucial obstacle to the implementation of the CE as different economic priorities exist, especially in developing countries. MH, however, states that industrialized nations should construct the required infrastructure and assume responsibility, therefore increasing demand and acceptance of developing countries. The communication and education challenges are stated as the primary hurdle by CP, TE, PdH, and HK, which can be resolved through regulations, laws, and incentives, such as taxes. According to these arguments, the acceleration potential of AI was deemed minimal, and it could only aid in supporting communication channels.

Barrier 10) - Inflexible Policy and Structures

Based on previous literature the last barrier, barrier 10), was also expected to greatly constrain C-SC. However, this hypothesis was only partially supported. MH notes that this barrier is particularly significant regarding cross-border collaboration. Despite being viewed as the foundation of the circular transformation by DK, TE and HK point to the numerous regulations that have already been enacted due to the EU goals. Despite the tightened regulations that indicate the importance of the barrier, HK also states that progress has been very slow. CP, MH and PdH point out that AI can help to overcome this barrier by assisting in understanding the various regulations through pattern recognition and by creating a data-oriented platform to support the formation of C-SC. Most importantly, AI can aid in structuring the vast amount of required information.

7.4.2 Additional Barriers

The role of regulations has already been addressed in the assessment of the different barriers, but is found to take on two different dimensions. CP identified regulations as an additional barrier obstructing the establishment of new C-SCs. Contrary to CP, MH cited them as advantageous for C-SCs due to the detailed information required by the new regulations, so that sectors need to work closely together, considering regulations as an enabler. Another barrier mentioned by MH is a lack of knowledge within the sectors, e.g., among employees, which is related to the different understandings of the term CE (Kirchherr, Reike, and Hekkert 2017). Additionally, DK states that a sectors' strategic priorities can be identified as another barrier. This issue is addressed in the consideration of barrier 2), but it relates to a higher, more strategic, level above the operational and management practices. Finally, TE refers to the unavailability of CE-oriented partners as a barrier. For example, despite companies' ambitions for a CE, there is an overall shortage of suppliers and the materials they provide.

7.5 Discussion

In this research study, AI has demonstrated a beneficial impact in addressing pressing challenges encountered by C-SC in the CE. The importance of these challenges has been assessed and expanded to reflect the current obstacles facing industries in the present environment. The outcomes indicate that there are significant hurdles that must be overcome for effective C-SC to occur and for the CE to advance. Nevertheless, AI applications have the necessary capabilities to facilitate this transition. It is noteworthy that expert interviewees identified four additional barriers that are putting pressure on collaborators. Appendix C8 shows that cultural barriers 6) and 9) (*cluster 1*) were identified as having a high importance for C-SC in CE, but they fall outside the scope of support from AI applications. *Cluster 2* consisting of barriers 2), 8), and 10), show moderate importance for C-SC in CE and limited options for AI support to overcome them, as indicated by their placement in the middle of the

matrix. These barriers were considered less pressing, particularly for C-SC. Lastly, barriers 3), 4), 5), and 7), *cluster 3*, present the greatest potential for AI to expedite barrier removal. Pattern recognition, data processing, analytics, monitoring, and generative AI are some AI applications increasing knowledge exchange between sectors. Furthermore, the framework established (Figure C2) highlights AI application use cases that offer guidance for future C-SC developments in the CE. The three clusters depicted illustrate the specific domains - *data transparency*, *data integration*, and *data orchestration* – in which AI can enhance the workflow within a cluster, and where it has the greatest potential to help overcome C-SC challenges and effectively promote overall C-SC. The distinct three domains aim to provide sectors with specific guidance to avoid future C-SC challenges in the CE:

Data transparency relates to making data more visible, understandable, and approachable to support communication channels and address cultural challenges.

Data integration involves handling unstructured data, such as for risk assessment, harmonizing data to create synergies and data platforms, and improving regulatory understanding through pattern recognition.

Data orchestration reflects the highest potential for C-SC by acting as a mediator between sectors, especially through data analysis, but also through data management and storage, for example using data sharing platforms.

AI presents significant potential for enhancing C-SC, but it should not be viewed as a standalone solution to the analyzed barriers. Furthermore, the development of individual technology systems (barrier 1) is a crucial prerequisite for AI applications to provide support for C-SC in the CE.

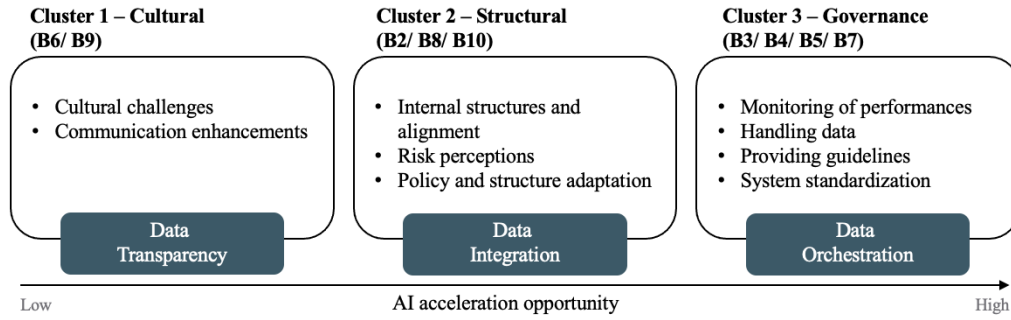


Figure C2. AI-use case clusters depict AI-enhanced opportunities for C-SC (Source: Own illustration)

7.6 Theoretical and Practical Implications

The results of the empirical study, as demonstrated by its relation to the literature review, are a valuable addition to previous research on the role of AI for C-SC in the CE. The study successfully verified and extended the barriers previously identified by Luthra et al. (2022), and defined clusters of AI application use cases. Additionally, it effectively detailed the cross-sector strategy, Industry 4.0, to overcome 17 barriers by exploring AI possibilities for 10 of them (Luthra et al. 2022). Also, the challenges described by Bates (2023) and Bryson, Crosby, and Stone (2006), were supported by the interviewee's responses. Additionally, the AI use cases, as identified by Mikhaylov, Estève, and Champion (2018), were endorsed by the interviewees, highlighting the necessity for learning and adaptation in C-SC, as suggested by Bryson, Crosby, and Stone (2015). The findings make a valuable addition to the existing research by highlighting how appropriate AI implementation can effectively address certain C-SC barriers. Sectors exploring circularity options should consider the practical implications of the results to ensure successful collaboration. Preparation of various stakeholders is needed for the application of AI tools for circular initiatives, considering the associated challenges. Each of the underlying issues discussed in the barriers provides guidance for different stakeholders and sectors on how to avoid creating barriers in the first place, thereby promoting effective C-SC from the outset. Trust among collaborators is necessary for data sharing to initiate and AI applications to be established. However, investment in well-equipped IT

infrastructure is essential for collaboration to occur in the first place. Unlocking AI's full potential requires building upon the defined use cases and creating new regulatory structures.

7.7 Limitations and Future Research

Although this research provides valuable insights into how AI can address specific C-SC barriers in the CE, it has its limitations, and further research is recommended. It is crucial to note that the selection of barriers is dependent on the intersection of two vast megatrends that are being brought together. Therefore, it is possible that the selected barriers from Luthra et al. (2022) led to certain perspectives being less considered beyond those proposed. Acknowledging that this study is a snapshot of the current environment and may change as regulations become more rigid in the coming years, is essential. Therefore, it would be interesting to shed light on the additional barriers found. Additionally, the role AI has in cultural dimensions should be further examined in future research. Moreover, future research addressing the development of various AI use-case clusters will be intriguing, to further explore upcoming AI applications. Furthermore, this study solely examined AI applications, therefore, analyzing the potential interactions between different digital technologies would be appealing.

8 Discussion

Concluding on the overall research question “*What is the impact of AI on the circular economy building blocks: Circular Product Design, Circular Business Models and Cross-sector Collaboration?*”, the summarized findings jointly indicate that AI has a positive impact on the CE. Based on the conducted interviews, a comprehensive framework has been developed integrating collective insights (see Figure 2). This circular framework depicts three essential layers crucial for understanding the synergy between AI and CE, following an outside-in perspective. The initial layer comprises three distinct AI applications – AI-based algorithms, predictive AI, and generative AI – serving as the foundational elements for enhancing CE

Group Part

practices. Notably, the research emphasizes the most promising AI applications identified through the deep dive analysis in the specific building blocks. The second layer, intricately shaped by the first, highlights the significance of the interplay between AI and the three building blocks of the CE. A detailed exploration of circular product design, circular business models, and cross-sector collaboration barriers unveils AI's significant potential to disrupt each of these domains, fostering product integrity, circular advantage, and cross-sector collaboration, respectively. This is elucidated in the third layer, the core of Figure 3. Thus, the developed framework not only consolidates key insights but also illuminates the ways in which AI positively shapes and enhances the CE across its fundamental building blocks.

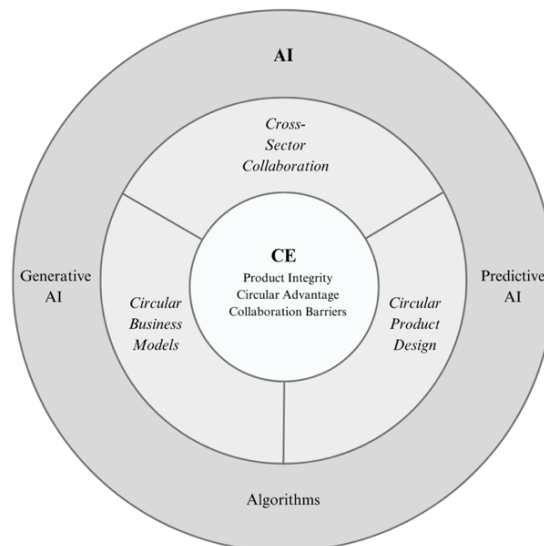


Figure 2. Circular Framework addressing AI's critical role to secure a more resilient and effective CE (Source: Own illustration)

To highlight the potential of AI, the following section summarizes the specific applications of the three AI technologies within each building block. *AI-based Algorithms* as an application were evaluated across all building blocks, but different underlying use cases were identified. For instance, leveraging previously collected and analyzed data, deep learning algorithms excel at recognizing patterns from sketch and fabric information, offering innovative suggestions for new designs. Trained deep-learning algorithms further contribute by

comprehending complex material compositions, providing designers with valuable insights to optimize material selection. However, use cases for circular business models slightly differ from those used for product design. First, AI-based algorithms can be used for route optimization of EoL products, minimizing transportation emissions. Object recognition algorithmic model can enhance waste management by automating the sorting processes of take-back systems and tailored end-of-rental suggestions improve the customer experiences of leasing businesses. Next, recommendation algorithms optimize sharing platforms, encouraging circular consumption. Sentiment analysis gathers transparent customer feedback, shaping responsible business model. These integrated approaches foster sustainability, efficiency, and innovation within the Circular Economy framework. In the context of cross-sector collaboration, it becomes apparent that pattern recognition is the primary use case for this type of AI application. Using this application among collaborators expedites the establishment of synergies for goal setting and managing large amounts of unstructured data. The resulting alignment of interests ensures a stable foundation for C-SC. Additionally, AI can support the development of sharing platforms to structure collaboration. These platforms have proven to be crucial for customer-related use cases and are therefore also very important for circular business models.

Predictive AI has a significant potential for the CE. Specifically, in circular product design, it largely aids in conducting simulations. Predictive AI in product design thrives in managing sustainability trade-offs by swiftly calculating and comparing potential future product impacts. This can guide material selection decisions as well as how a product should be assembled. Moreover, predictive AI can conduct sensitivity analyses, refine prototypes, and ensures product integrity by predicting wear, enabling proactive maintenance scheduling, and facilitating end-of-life recovery. Next, predictive AI is also pivotal in circular business models, excelling in predictive maintenance and demand forecasting. It anticipates potential

failures in industrial machines, manages remanufactured materials, and optimizes customer experiences in leasing models. Its capabilities extend to proactive recommendations for personalized training or product upgrades, notably in the manufacturing sector. Cross-sector collaboration also emphasizes the importance of time-series data, particularly in risk prediction and assessment. As different risk perceptions are found within the different sectors, predictive AI assists in evaluating and communicating these for an effective collaboration. Furthermore, it can assist in simulating decisions among collaborators in different sectors.

Generative AI is the final AI application, focusing primarily on communication and translation purposes, which includes a more creative application rather than pure data analysis. Generative AI revolutionizes product design, for instance, by crafting innovative material combinations aligned with predefined criteria, actively creating novel compositions for reduced environmental impact. Furthermore, generative AI extends its influence to generate personalized and unique circular designs, tailoring products to individual user preferences and emphasizing emotional durability. For circular business models, generative AI primarily assists with communication processes directed at consumers and businesses. Chatbots can facilitate communication between businesses and consumers throughout different stages of the product life cycle and across the value chain. Together with AI-based algorithms, generative AI is also one of the main factors for cross-sector collaboration. Primarily, the application supports knowledge transfer by accurately translating and facilitating mutual understanding of various data types, acting as a mediator between different sectors.

Based on the three building block's key findings, the study finds a positive impact of AI on the CE. First, within circular product design, a positive relationship emerges as it significantly influences the integrity of a product and hence its circularity. Second, in the domain of circular business models, the research identifies a positive reciprocal relationship, indicating that AI contributes to achieving a circular advantage. Last, in the context of cross-sector collaboration,

a positive impact is evident as AI assists in overcoming collaboration barriers associated with CE. Collectively, these findings underscore that AI, operating across these diverse domains, plays a pivotal role in positively impacting the CE.

9 Implications

9.1 Theoretical Implications

Combining the various results found throughout the study, they successfully complement the findings discussed in the literature review. The discoveries of Abdelhafeez and Ramakrishna (2021) on the opportunities for AI to revolutionize the transition to greater circularity are found to be confirmed across all research questions. The different building blocks pointed out by the Ellen MacArthur Foundation (2011) provided a very sufficient basis for the research at hand. However, it was possible to provide further details about the evolving interaction between AI and the various building blocks. The potential of AI in product design emphasized by Roberts et al. (2022), surpassed the scope of its significant data analysis capabilities, as it examined the specific potential of AI, such as pattern recognition, predictions generative modeling across the various phases of product design. Moreover, this study sheds light on the findings regarding circular business models. Schroeder, Anggraeni, and Weber (2019) highlight the increasing innovation in circular business models, which is further validated by exploring the different options that AI has to accelerate the transition from linear to circular business models. Finally, the literature on cross-sector collaboration, especially by the Ellen MacArthur Foundation (2019), highlighted the importance of CE innovation taking place across industries. This has been successfully detailed by evaluating different AI use cases that successfully tackle C-SC barriers.

9.2 Practical Implications

Practical implications arising from the study's findings highlight the imperative for companies, governments, and practitioners to actively incorporate AI into CE initiatives.

Companies should prioritize raising awareness and educating stakeholders about AI's positive impact on circular design, business models, and collaboration. The adoption of the study's framework as a blueprint is crucial for guiding managers in adapting strategies. Identifying potential AI applications such as generative and predictive AI and how to use them in product design, business model innovation and to overcome collaboration barriers, is a crucial task for designers, managers, businesses, and entire ecosystems at large. This shows the need for ongoing education and the cooperation of managers. In other words, collaborative efforts between CE experts, businesses and their managers, as well as AI technical experts are essential for exploring opportunities and driving innovation. Adopting a holistic approach, companies should integrate AI solutions across the entire value chain and forge ecosystem partnerships for comprehensive CE implementation. Moreover, governments should foster a safe and central data space which is the basis for AI applications. To summarize, both companies and governments should recognize AI's strategic importance and incentivize its adoption through targeted policies and financial support. In essence, the practical implications underscore the need for a concerted effort to embrace AI as a catalyst for CE practices.

10 Limitations and Future Research

In examining the role of AI within the CE, certain limitations in the current study prompt considerations for future research. One notable limitation is the reliance on six experts which may restrict the diversity of perspectives resulting in potential biases. To mitigate this limitation, future research should apply a more inclusive approach by incorporating insights from a broader spectrum of stakeholders, including industry professionals, academics, and end-users. Additionally, future studies could concentrate on examining the three building blocks within one industry. This targeted approach would not only yield industry-specific recommendations but also provide a comprehensive blueprint on how AI can strategically benefit diverse types of company structures within the CE framework. Another constraint lies

in the qualitative nature of the data obtained through in-depth interviews. While these interviews offer rich insights, the absence of quantitative data limits the study's ability to draw statistically significant conclusions. To strengthen future analyses, a mixed-methods approach could be beneficial, combining qualitative depth with quantitative breadth. Given that the current research primarily focuses on assessing the potential of AI integration and recognizing suitable AI applications along the three building blocks, future research should shift towards an exploration of the internal capabilities' requisite for such digital transformation. This involves a meticulous examination of how companies need to be structured to effectively leverage AI within their operations. Thus, prospective research should scrutinize the interplay of prerequisites necessary for successful AI adoption, including considerations of workforce skills and the organizational setup, such as robust data ecosystems.

11 Conclusion

In conclusion, this paper underscores the pivotal role of AI as a catalyst for the transition towards a CE. Drawing insights from in-depth semi-structured expert interviews, the research highlights the significant potential of different AI applications in the areas of product design, business models and cross-sector collaborations. Collectively, these applications form a robust foundation for enhancing circular flows and optimizing resource efficiency. The study introduces a novel framework that not only underscores the affirmative influence of AI applications on each building block, but also illustrates their collaborative power in promoting a CE. The synergy between AI and CE principles represents a transformative pathway, not only contributing to economic growth but also sustainable resource utilization. This paper serves as a call to action, urging stakeholders to explore, adopt, and promote AI applications across all three building blocks of the CE. By doing so, firms can capitalize on the immense potential of AI to drive positive environmental impact, economic growth, and innovation in a circular and sustainable manner.

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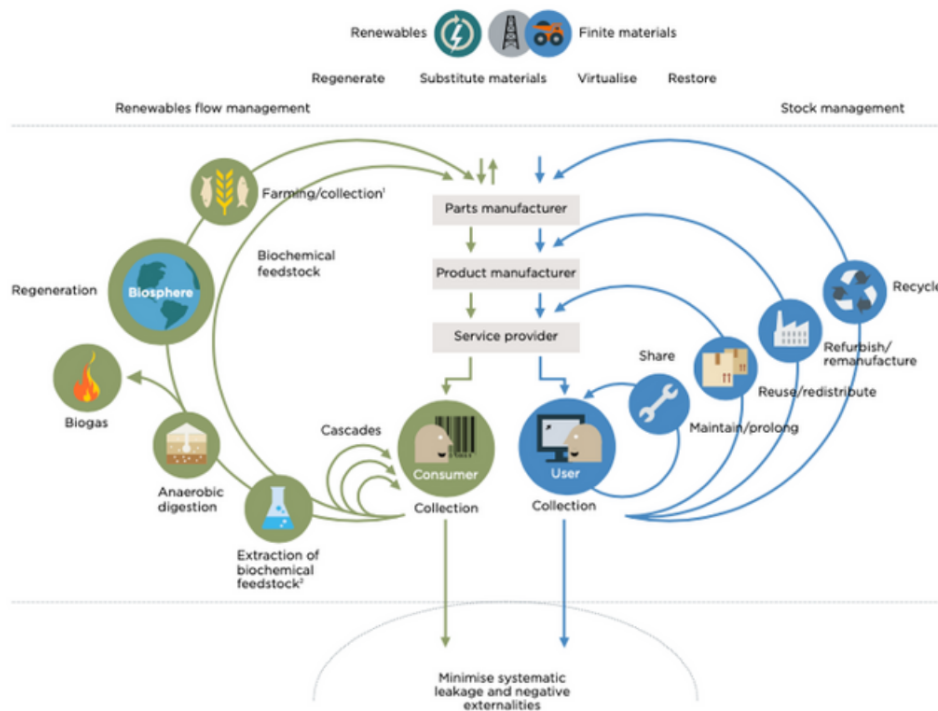
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13 Appendix

Appendix 1. The CE system diagram by the Ellen MacArthur Foundation 2019. “Artificial Intelligence and the Circular Economy - AI as a Tool to Accelerate the Transition.” *McKinsey & Company*.



1. Hunting and fishing
2. Can take both post-harvest and post-consumer waste as an input

Group Part

Appendix 2. The six major components of AI by Kanade, Vijay. 2022. “What Is Artificial Intelligence (AI)? Definition, Types, Goals, Challenges, and Trends in 2022.” Spiceworks. March 14, 2022.

Components of AI	Description
Machine Learning (ML)	Machine learning is an AI application that automatically learns and improves from previous sets of experiences without the requirement for explicit programming.
Neural Networks	Neural networks are computer systems that are loosely modeled on neural connections in the human brain and enable deep learning.
Deep Learning	Deep learning is a subset of ML that learns by processing data with the help of artificial neural networks.
Cognitive Computing	Cognitive computing aims to recreate the human thought process in a computer model. It seeks to imitate and improve the interaction between humans and machines by understanding human language and the meaning of images.
Natural Language Processing (NLP)	NLP is a tool that allows computers to comprehend, recognize, interpret, and produce human language and speech
Computer Vision (CV)	Computer vision employs deep learning and pattern identification to interpret image content (graphs, tables, PDF pictures, and videos).

Group Part

Appendix 3. Expert interview descriptives (Source: Own illustration)

Day	Interview style	Name abbreviation	Position & company	Area of Expertise	Length in minutes
November 7	MS Teams	CP	Co-Founder & Managing Director of a Sustainability Consultancy	CE	60
November 10	MS Teams	MH	Sustainable Business Lead at a European State Research Institute	CE & AI	60
November 13	MS Teams	DK	Circular Economy Researcher & ESG Transformation Manager	CE & AI	60
November 16	MS Teams	TE	Partner Value Chain Strategy & Transformation at a Consultancy	AI	60
November 17	MS Teams	PdH	Vice President, AI, Research & Advisory at a Research Company	AI	45
November 17	MS Teams	HK	Associate Consultant in the Circular Operations Practice	CE	60

Group Part

Appendix C1. Circular supply chain management loops by Hazen, Benjamin T., Ivan Russo, Ilenia Confente, and Daniel A. Pellathy. 2020. "Supply Chain Management for Circular Economy: Conceptual Framework and Research Agenda." *The International Journal of Logistics Management* 32 (2): 510–37.

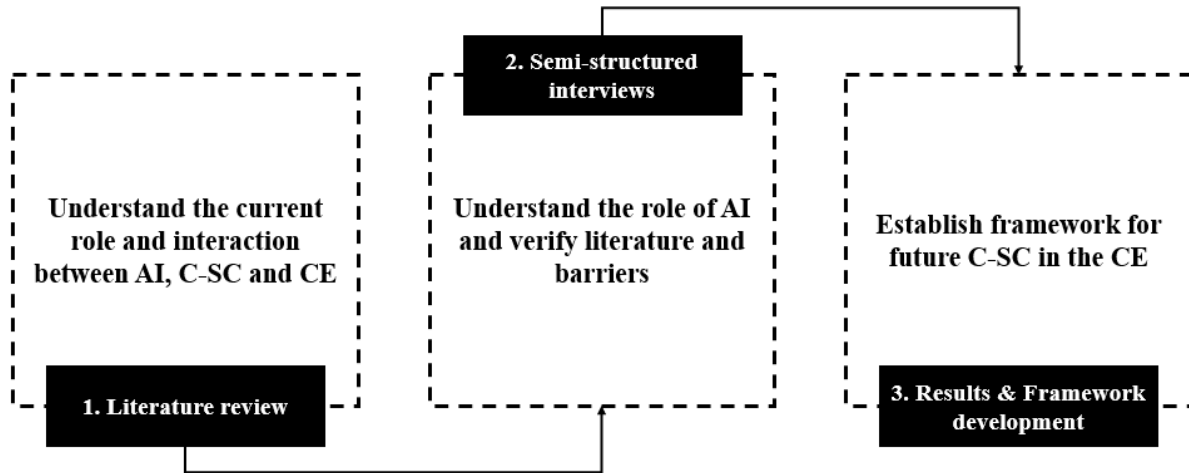
Strategy	Description
Closing loops	Defines the practice materials reuse through the recycling, remanufacturing, and similar processes.
Slowing loops	Is about prolonged use and reuse of goods over time, through processes such as designing durable goods and product lifecycle extensions.
Intensifying loops	Suggests a more value-intensive use phase of materials or products, such as by promoting pooled or shared product usage vice individual consumption.
Narrowing loops	Concerns overall resource efficiency, using fewer resources per product.
Dematerializing loops	Refers to substituting products for services in a way that increases utility and longevity of products and materials.

Group Part

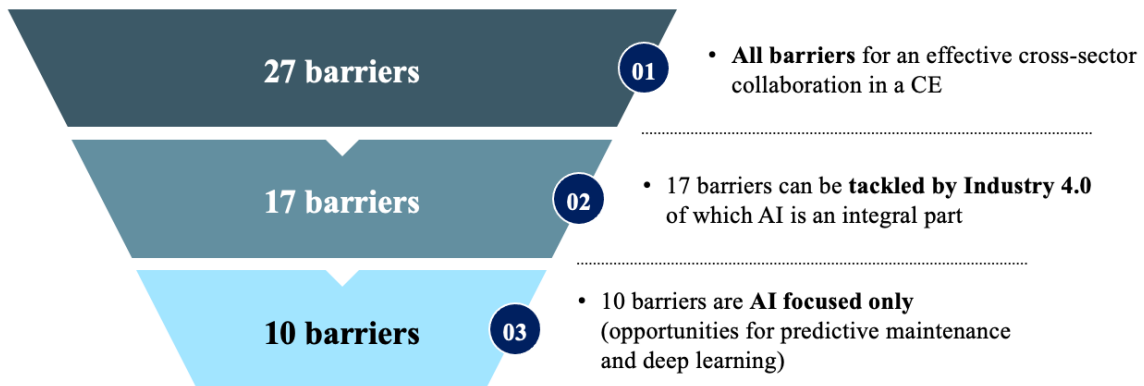
Appendix C2. 27 barriers by Luthra, Sunil, Manu Sharma, Anil Kumar, S. K. Joshi, Eva Collins, and Sachin Kumar Mangla. 2022. “Overcoming Barriers to Cross-Sector Collaboration in Circular Supply Chain Management: A Multi-Method Approach.” *Transportation Research Part E: Logistics and Transportation Review* 157

No.	Barrier	No.	Barrier
1	Temporal dynamics of technology	15	Internal bureaucracy
2	Distinct operational and management practices	16	Lack of common vision and policy framework
3	Monitoring performance within multiple contexts	17	Competition vs. collaboration
4	Risk of information loss	18	Absence of system standardization for performance management
5	Loss of control over operations	19	Risk management approaches
6	Duplications of responsibility and authority	20	Limited knowledge/ experience among decision makers
7	Lack of transparency and low-quality disclosures	21	Absence of commitment by organizations towards sustainability
8	Incompatibility with the corporate “immune System”	22	Poor demand/ acceptance for environmentally superior technologies
9	Diverse institutional logics	23	Inflexible policy and structures
10	Organizational norms and culture	24	Lack if legitimacy
11	Inbuilt organizational resilience	25	Command-control government regulations
12	Misaligned interests of individuals across sectors	26	Lack of power asymmetry
13	Lack of social movements	27	Isomorphic institutionalism
14	Lack of trust among cross-sector collaborators		

Appendix C3. Research Design (Source: Own illustration)



Appendix C4. Methodology process to extract final barriers (Source: Own illustration)



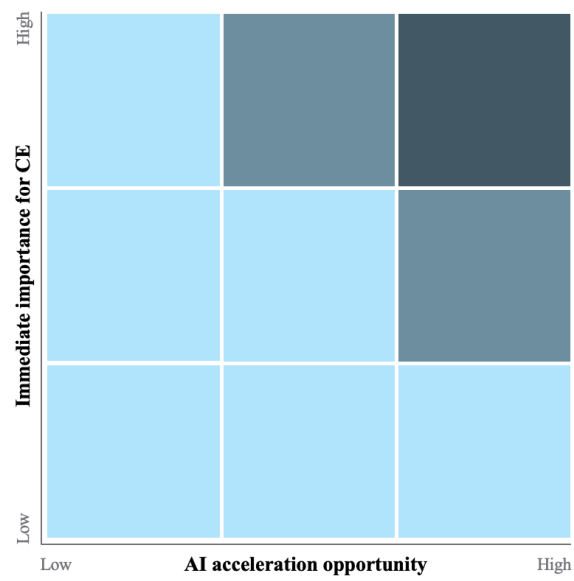
Group Part

Appendix C5. Final barriers adapted from Luthra, Sunil, Manu Sharma, Anil Kumar, S. K. Joshi, Eva Collins, and Sachin Kumar Mangla. 2022. “Overcoming Barriers to Cross-Sector Collaboration in Circular Supply Chain Management: A Multi-Method Approach.” *Transportation Research Part E: Logistics and Transportation Review* 157

No.	Barrier	Description
1	Temporal dynamics of technology	Differences exist in the temporal dynamics of technology among partners; this restricts ability to collaborate for circular supply chain management (CSCM).
2	Distinct operational and management practices	Sectors are restricted by their independent planning and management practices and are thus unable to develop integrated planning toward CSCM.
3	Monitoring performance within multiple contexts	Stakeholders monitor performance in different contexts creating complexity in developing C-SC for CSCM.
4	Risk of information loss	Employees and managers do not know what information can be shared to support collaboration for CSCM and thus worry about information loss.
5	Lack of transparency and low-quality disclosures	Different stakeholders may be reluctant to share information and disclose information; this may act as a barrier for C-SC for CSCM.
6	Misaligned interests of individuals across sectors	Individuals can become misaligned when their interests do not match. The mismatched interest may hamper C-SC to develop CSCM.
7	Absence of system standardization for performance management	Lack of pre-defined systems to measure the impact of collaboration as well as lack of parameters to evaluate costs and savings for developing CSCM.
8	Risk management approaches	Different sectors have their own autonomous approaches to perceive and mitigate risk. Thus, it is difficult to manage among partners/ collaborators across sectors.
9	Poor demand/ acceptance for environmentally superior technologies	Due to lower awareness, the demand for superior technology is less in developing nations. It restricts collaboration across sectors for implementing CSCM.
10	Inflexible policy and structures	The economy is still lacking an adaptive structure to support C-SC for CSCM.

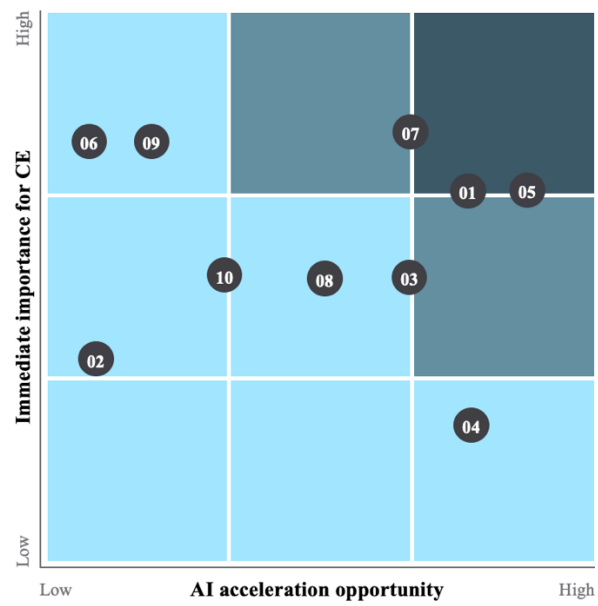
Group Part

Appendix C6. Interview Matrix (Source: Own illustration)



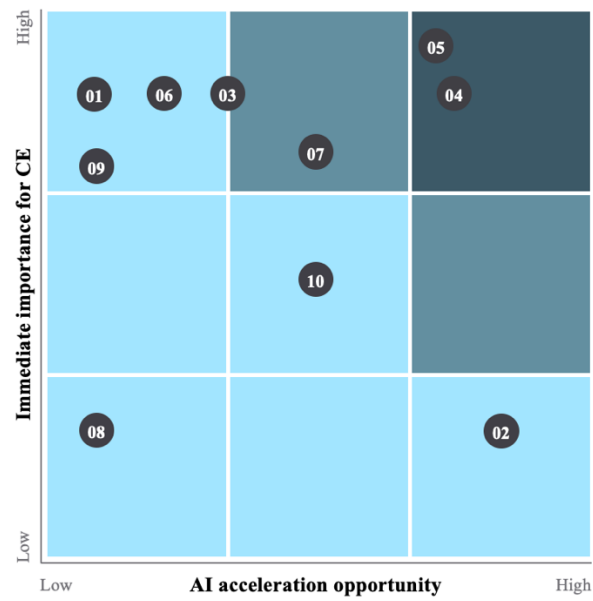
Appendix C7. Individual Interview Matrices (Source: Own illustration)

Interview 1 - CP

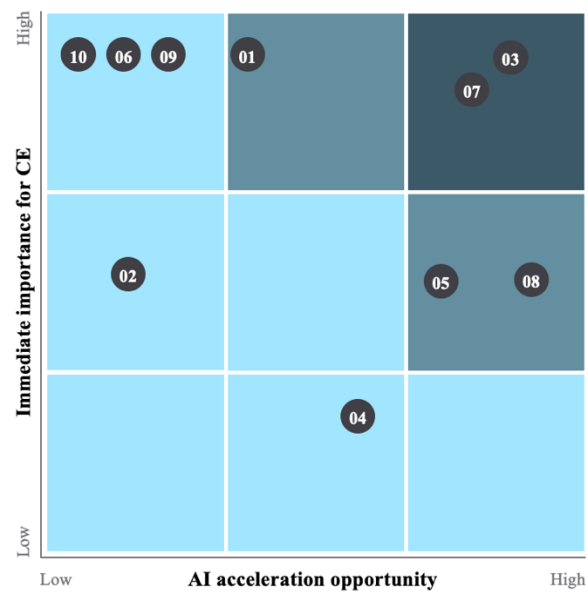


Group Part

Interview 2 – MH

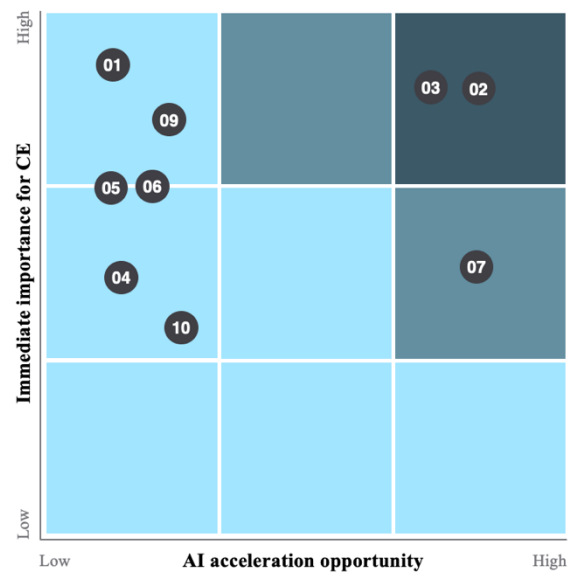


Interview 3 - DK

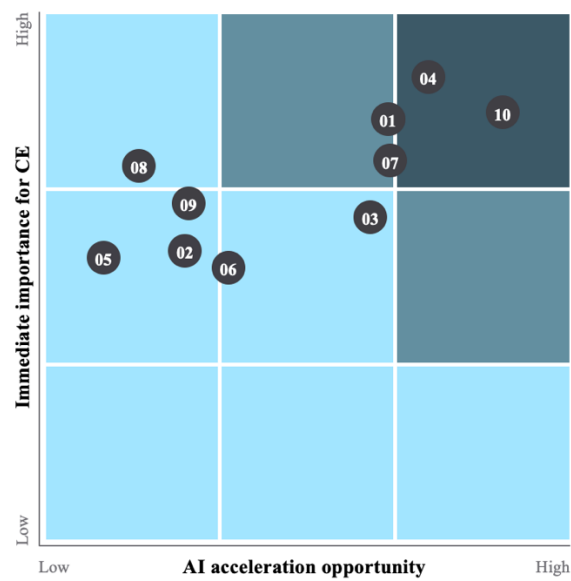


Group Part

Interview 4 - TE

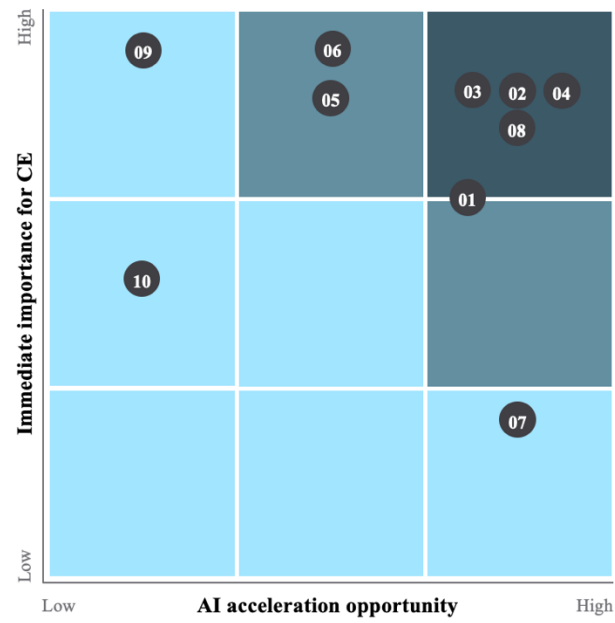


Interview 5 - PdH

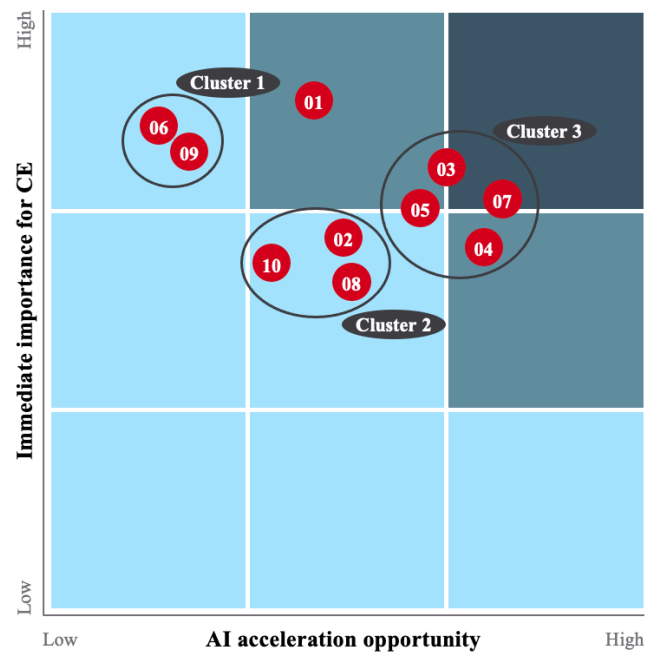


Group Part

Interview 6 - DK



Appendix C8. Empirically driven development of AI use-case clusters (Source: Own illustration)



Appendix D1. CP's interview transcript

CP

Hello, thanks for inviting me today. My name is CP. I'm a senior expert in the field of sustainability. I've worked mostly in the automotive industry in the sustainability space for more than 10 years now. Since 2019, I was subject matter leader for the field of circular economy, mostly in the space of the automotive industry, but also branching out to other consumer products such as glasses or cables. My education background is engineering. But that's, uh, doesn't uh contribute much, so I'm very happy to to answer questions.

Lena Sophie Thielmann

Thank you very much. Very nice to meet you and let's start right up with the first question being how do you see the current developments in circular economy in general?

CP

The current developments for circular economy are maybe to be seen in two dimensions. First, there is a lot of hope around circular economy as resource efficiency becomes more tangible across all sectors of industry, that's the one world.

So there's a lot of sort of hype around it.

The second site that I see is that it's hard, at least for companies to actually implement circular changes, because well, I wouldn't say the reasons already, but it's hard to implement, so a lot of hype and hard to implement would be the summary on how I see the current space.

That comes mostly from an industry out of long lasting consumer products like cars and we always try to do segments of what do you have in terms of what's the average lifespan of the product or the company that you're looking at.

Let's see from a car or even a ship or machine with 10 plus years of investment to single use straw for instance.

So that needs to be differentiated in that spectrum maybe?

Lena Sophie Thielmann

And did you have like, an impression on how AI is currently developing in the field or do you have any experience in that regard?

CP

What we could see in the past is that circular economy had a lot of hurdles to.

To get implemented the second part that I'm in the question now is how?

How AI can work and maybe we need to see how technology or digital technologies in general can help and then how AI specific can help.

I would look at that in two stages and for the automotive industry, one of the big challenges in the field of data and technology was the availability of data and quite literally the email I sent 30 seconds before we met was to an automotive company on trying to understand their data on their materials.

Group Part

44 So I think and that I need to put that as disclaimer, I'm more expert on the circular economy,
45 not so much on the AI, but I can explain that the availability and the accessibility of data
46 from materials is crucial in order to work with circularity approach of the materials.

47 I often don't know what materials are in my products.

48 So let's say data availability is a huge challenge, and therefore that context.

49 If AI were to help with data availability, that would be huge progress for Circularity.

50 This is now speaking for the large consumer.

51 The products like cars, but if you look at, I mean think about yourself or the end consumer,
52 when you have plastic packaging for instance, how you recycle and that they can be now
53 seen from a German or from EU, European perspective, what do you do with the stuff you
54 throw away?

55 So you don't know the question would be how I could enable consumers at the end of the
56 life cycle, for instance, to better recycle, so to say or what to do with the materials.

57

58 **Lena Sophie Thielmann**

59 Yes, that's actually in the perfect transition to the first topic that we wanted to deep dive in
60 today because the availability of data is something that is currently also present in research.

61 A very recent topic and one possible strategy to overcome this lack of data is actually
62 collaboration between different sectors.

63 So not only between companies, but only also upstream and downstream of the supply chain
64 with the public and with governmental institutions.

65 So, the part I'm focusing on is the role of cross-sector collaboration in circular economy and
66 how AI can help the transition to more collaboration.

67 So to start with the topic, I had a look at the different barriers of cross sector collaboration in
68 circular economy in general.

69

70 **CP**

71 Mm-hmm.

72

73 **Lena Sophie Thielmann**

74 Those were 27 barriers that the paper by Luthra found, and those could were able to be
75 broken down to 17 because they found that industry 4.0, of which AI is an integral part and
76 can actually help to overcome 17 of those.

77 But industry 4.0 is not AI itself, so it's not a synonym for for AI.

78 And that's why I broke it down to 10 barriers.

79

80 **CP**

81 Mm-hmm.

82

83 **Lena Sophie Thielmann**

84 Which AI can actually have an impact on and the idea would be that we now look at those
85 barriers and first of all rank them in their importance for circular economy in general.

86 So that would be probably your field of expertise.

Group Part

And then maybe with your experience that you saw in the field already in which barriers do you think technology or AI could have the main impact so?

CP

Alright, understood.

Lena Sophie Thielmann

OK.

OK, so I would just quickly go through the 10 barriers.

It's a lot of text, but it's just an explanation beneath.

So the first one is that we currently have different status quos of technologies among different partners.

So they all have different IT systems and those would need to be aligned in order for the collaboration to be successful.

CP

Mm-hmm.

Lena Sophie Thielmann

The second one is that, the different partners in sectors have different or independent planning and management practices on how they tackle things and how they measure those things. And the third one being monitoring performance within multiple contexts.

That means that stakeholders monitor performance differently among different sectors in context. So mostly like company focused performance monitoring in this case then the 4th barrier being risk of information loss. So it is unsure on what needs to be shared. What should be shared and how is this stored later on? The fifth one, lack of transparency and low quality disclosures, which is also more about the type of information that is shared and the quality of this information, which, could be very different among the different partners.

Then we have the misaligned interests. Because, individuals or sectors have different interests on how they prioritize their goals. And that could be an essential barrier to collaboration. Then we have the absence of system standardization for performance management. So how do you actually measure the impact of the collaboration itself? Then we have risk management approaches. So the different sectors measure risk in different and ways and also perceived risk in different ways. And then the 9th one is poor demand acceptance for environmentally superior technologies. So how is the awareness in general towards those accelerated and technologies? And then of course also currently the problem of very inflexible policy and structures, which would be an enormous barrier for collaboration in general.

So maybe in case you don't have additional questions about those barriers, we could dive into it or if you already have an impression on how you would see the immediate importance maybe of those barriers for just circular economy in the first step and then afterwards, after

Group Part

129 we have the Y axis, the idea would be to see, OK from which barriers onwards do you see
130 there maybe an AI acceleration opportunity from your experience.

131

132 **CP**

133 OK.

134 That's good.

135 That's quite an interesting collection, so let's see and it's important that we align on the
136 headline here that it is on the collaboration now and that is mostly multiple sector people.
137 How they can work together? It's the collaboration.

138

139 **Lena Sophie Thielmann**

140 Yes. There's like, it's and it's business, business, business and public, governmental and
141 public business and governmental. So every kind of cross sector collaboration, because the
142 definition is that this type of collaboration actually aims to overcome societal problems such
143 as the environmental impact currently being. So that's the idea and that's why we chose this
144 exact type of collaboration in this case.

145

146 **CP**

147 Understood, I would even narrow it down to collaboration in general even within the
148 automotive industry if you want to work within the supply chain. We struggled in the past a
149 lot to get the OEM and the Tier 1 and Tier 2 supplier to redesign gearboxes for
150 remanufacturing, for instance, just within one industry is already complicated if you want to
151 see it across sectors, it makes it, that makes it even more tricky, but that's fine.

152

153 Then let's see what we can do with the first one. Temporary dynamics of technology. So the
154 differences with the different partners. Umm, I will put that in the top left. Why is that?
155 Because the further you go down the supply chain, the more you find differences. There's
156 huge differences in technology that will work and this also across actors, like the chemistry
157 industry is way, way far advanced and the automotive industry.

158

159 Then distinct operational management practices. Less important, let's put it in the lower end
160 of the middle sector.

161

162 Monitoring performance. The monitoring is between one and two because it's crucial later
163 that you can also track for instance, how much circular material it was in a certain product.

164

165 Risk of information loss. The lack of information, lack of transparency, low quality
166 disclosure, the risk of information loss. Uh, I would put it below the #2. I personally think
167 there is not so much risk that information gets lost.

168

169 Lack of transparency, low quality disclosure that is high, so #5 is close to number one. You
170 can actually put them next to each other. That's what I meant earlier. It's one of the major
171 challenges with the transparency and information available.

172
173 Misaligned interests, that is, maybe even above #1 because a lot of businesses and business
174 models depend on the linear business models with fast consumption. Think fast fashion for
175 instance. There's very little incentive for repairability. Just try to fix jeans again, it's just
176 impossible.
177 #7 absence of system standardization and performance management. That's a huge one
178 where I invite you to look into the catina ex activities that the European or German industry
179 is doing. It's between one and three. Ah, no, it might be even higher to be honest, because it
180 makes it painful and also slow if the different actors don't speak the same language in terms
181 of standards.
182
183 #8 Risk management. Put it next to #3. Because here, particularly in the automotive space,
184 the designer wants to introduce more recycled metals for certain parts and then the customer
185 safety aka vehicle safety was always an obstacle there.
186
187 And then we have poor demand, acceptance of environmentally superior technologies. That
188 goes on the same level as six and seven because here we need to see that very often only
189 because something is recycled it's not necessarily better for the environment.
190
191 #10, inflexible policy and structure. This is a problem next to three and eight. I am thinking
192 about material regulations. A huge obstacle in terms of plastic recycling that cars or even
193 Lego bricks that have been produced 20 years ago due to changed legislation that can't be
194 recycled anymore nowadays. So they need to be burned.
195
196 **Lena Sophie Thielmann**
197 OK.
198 Thank you.
199
200 **CP**
201 OK, now we need to see how we shifted to AI.
202
203 **Lena Sophie Thielmann**
204 Exactly. So the idea of AI is that first of all, it helps to predict patterns among data and has
205 the opportunity to work with a huge variety of data.
206 Also it has the opportunity to detect anomalies among data and it can kind of, yeah, through
207 this pattern thinking it can learn among itself in a different in a specific setting.
208 And through this kind of learning and dealing with data, those use cases such as monitoring
209 and or detecting abnormalities, detecting similarities, those use cases kind of come upon
210 that.
211
212 **CP**
213 OK.
214 OK, then let's move them around.

Group Part

215 Number one, temporal dynamics of technology I think here because it's faster, it must be in
216 the right very far, very far right, because yeah, I would hope that AI helps to work with that
217 speed.
218 Distinct operational management practices #2 I would leave it pretty much where it is.
219 #3 again. Uh, at least in the middle, but let's think about that. Monitoring performance
220 within multiple context, maybe even higher, we can put on the line between section 2 and
221 Section 3.
222 Risk of information loss. I would hope that AI is on the same level as number one. To help
223 that information doesn't get lost and is handled with care.
224 Uh #5. You can shift it on the same line but on the right side next to number one. I would
225 hope that AI would help, particularly to get more speed on disclosures
226 #6 Misaligned interest of actors.
227 There I think AI has not much impact or can't much because it is a people problem.
228 #7 we can shift into the middle from my point of view even maybe more on the line. Again
229 on the same level as three, because with absence of systems of standards, maybe AI can help
230 to accelerate this.
231 #8 we can push it in the middle. Uh, right in the center of the of the of the map, because here
232 AI might have the chance to help with some transparency things to make risks more visible
233 in their context.
234 Moving to 9 it is mainly only in communication. Nine, we have to push even a bit inwards.
235 And then inflexible policy and structure. Think we can put a bit to the left? I don't see how
236 AI can help with the policies unless AI helps to understand the policies and finds a way to
237 basically like to a black list or white spot analysis on where analysis is. Put it maybe a bit on
238 the line between one and two. Umm for the aspect where AI can help to identify white spots
239 in the legislation so I can put certain product there.

240

241 **Lena Sophie Thielmann**

242 I thank you so much for your insights and your sharing of your experience.
243 And before we start with the second individual part, my last question would be, do you miss
244 any specific barrier?
245 Is there anything you think off in the field of cross sector collaboration, CE and AI?
246 Do you think there's something missing in this regard?

247

248 **CP**

249 Good question.

250

251 Do we have regulation?

252

253 **Lena Sophie Thielmann**

254 Not specifically at the moment.

255

256 **CP**

257 It could be part of standards, but regulation is a huge barrier because it prohibits things both

on the AI side and also on the actual circular economy side, think about the legal bricks 20 years old that you can't recycle. Or it also accelerates it, if you think about the single use straws, for instance. So regulation. Something to probably think about. And then it's not so much on the on the collaboration. Uh, but the the the willingness to pay for clients sometimes. Even they could. Ecologically, it doesn't make sense to fix or repair jeans or certain products and just burn them because of the logistics effort. Think about Amazon returns. For instance, umm, it's just not feasible to deal with them. To summarize there I would look into barriers that have the target in mind. The client, the user or the customer doesn't necessarily need to be one, but sort of market acceptance.

Lena Sophie Thielmann

Umm, OK, thank you very much.

CP

You're welcome.

Lena Sophie Thielmann

Thank you very much for your time. I will now hand over to Annelie.

Annelie Sophie Steinbrenner

Thank you very much, Lena. So first, I will quickly share what my topic is about. I designed some slides as well.

So, to start off, my research focus lies in the middle between three main topics, artificial intelligence, circular economy, and product design and the focus of the research is how can AI be integrated in the circular product design.

So, I would like to start with a general question. Are there specific design characteristics or strategies that you believe are crucial for circularity?

CP

I worked in R&D for two years and was involved in the product design there as well. I think there's generally 2 approaches that you can take. One would be design for durability, which means the product will never break and the lifespan is very long. Let's make it tangible. Let's say the iPhone lasts seven years or something and you don't need to have it repaired. That would be great.

But the other approach would be to make design for disassembly where you make it easy to repair things where you have sort of regular maintenance.

And I think these are the two, at least for the for the automotive industry and the larger consumer goods, design philosophies in the product design.

Annelie Sophie Steinbrenner

That's perfect. So, that's exactly what I found and what you just confirmed that there are basically these two approaches on the left side of the slide, long use, and extended use. I think you told me about long use. And then for extended use, that's the second approach you mentioned that there's a lot of like regular maintenance.

What my question is here. Can you rank the different design approaches which we can see here from highest to lowest impact in terms of circular economy? And also, it would be very valuable if you also included your expertise from the automotive sector because I think there are definitely differences from sector to sector.

CP

Yeah. Thank you. That's good.

Well, the challenge is they're very conflicting. We have that, for instance, when you think of a Porsche, for instance, it's designed basically never to be recycled at the end. So, it doesn't matter about the recyclability of the material so much, because ideally, it's never going to be recycled.

It's different when you look at the Volkswagen Polo, for instance, where you have an end-of-life scenario already in mind.

So, you are right, it needs to be very specifically seen in sectors. When I do this ranking now, I would actually do that for an average car. For most of the volume of cars and not for specific use cases such as a Porsche.

It is tricky. Oh, I just read the first one. What is emotional durability?

Annelie Sophie Steinbrenner

So emotional durability is that you try to focus on the consumer very much and this is mostly luxurious goods. Saddle bags, old, good quality leather bags are one example. So, the leather bag is not only for physical durability but also emotional. So, the idea is that if the father buys a Saddle bag it's not only for him, but also then for the generations after him. So, it's not only about physical durability, but also about emotional durability to really appeal to people and to not really get outdated.

CP

OK. I've just a side note. Before I do the ranking, I would look at certain segments of consumer products and then the average lifespans and on the other axis, what's the global sales value a year? It is so different from sector to sector that you would always prioritize the circular strategies differently. It's too sector specific.

Umm for the car, extended use is probably the most important because the business model is that car parts are sold over time.

Three and four, maintenance and repair are more or less similarly important in extended use.

What is the interesting is what certain car manufacturers are looking at right now. For instance, Audi thinks about refurbishing and upgrading second hand vehicles. This is a new business model that is slowly coming. But of course three and four are the most important points for the automotive industry, maintenance and repair.

Annelie Sophie Steinbrenner

That helps a lot, yeah.

CP

And then, of course, long use. Design for physical durability is part of all cars. I mean they last at least 10 years. So that is already integrated.

348 **Annelie Sophie Steinbrenner**

349 Perfect. So just to summarize and clarify, extended use is what you think is in the
350 automotive industry, probably the most relevant one?

351

352 **CP**

353 Yes you can say that and number two, design for physical durability, is an underlying
354 principle for the industry.

355

356 **Annelie Sophie Steinbrenner**

357 OK. Perfect. And then, umm, as my last question. Also considering these different design
358 approaches, do you see for one of those or for several of those the potential of AI
359 applications? Or how AI applications in general can enhance circular product design in the
360 automotive industry?

361

362 **CP**

363 That's a good one.

364

365 **Annelie Sophie Steinbrenner**

366 To make it easier for you. In different studies it was found that these are some parts of the
367 design phase which could be improved by artificial intelligence. I was wondering what you
368 think of these AI applications? Or do you think of any other possibilities or design phases
369 where AI could help?

370

371 **CP**

372 That it's a good primer to put me in the right direction. What I would find very helpful is
373 managing conflicting targets.

374 I will give you a tangible example. We had that for the application of natural materials. For
375 instance, we replace plastic with natural fibers, which reduces the carbon footprint but
376 increases the water demand and increases the risk of human rights issues in the supply chain.
377 So, whenever you try to make something more sustainable or more circular, you have side
378 effects on other dimensions of sustainability, and if someone or some kind of AI technology
379 were able to rather fast simulate the different impacts that the design decision has, like
380 material choice decision. That would be a huge positive impact of AI on circular product
381 design. So that is one thing. Material choice decisions and summarize and compare the
382 implication different sustainability dimensions.

383 Then. Which I can imagine, and that was in the in the left one for designing for durability.

384 For instance, when you decide if you must make a material 1 centimeter thick or half a
385 centimeter thick. You half your material usage. If you were able to simulate if that material
386 could sustain certain requirements like, is it durable enough? So, kind of a stress test and
387 sensitivity analysis of a material. So you could simulate a lot around the durability
388 requirements. What would happen if I design the material like this or like that.

389 So that I think are two examples where AI could immediately help.

390 Think about car that are designed in some unique place in the world. But countries have
391 different country requirements. It would be great if AI could automatically account for these
392 country requirements in the design phase based on large data.

Or another example. Water is important in Mexico. It's not so important in Europe, at least in northern Europe. It would be interesting to see how I take notice and consider the different international requirements either as different targets or legal requirements. That would be the second huge impact of AI because governmental or geographical issues are so complex. No one understands all the regulation anymore and if AI could help here, it would make a lot of stuff better.

Annelie Sophie Steinbrenner

That's perfect. So, just to clarify one last time.

So, the main three things which you can see AI helping with is the material choice and the durability. And then thirdly, I think the third one was the international requirements, right?

CP

Yes.

Annelie Sophie Steinbrenner

Perfect. Thank you very much.

And maybe just to wrap it up at the end, what do you think is the biggest potential for AI in order to shift the entire automotive industry?

CP

I guess you can think in 2 dimensions. One is in the face of designing a car. What the car looks like. It would be interesting if AI could somehow help to design new layouts. Think of Tesla. The Tesla Model S looks about the same for 10 years now and it's the software that has been updated, which is why the cars don't need to be replaced so often. But unfortunately, they are not modern and stylish anymore. It would be great if AI could somehow keep them attractive, so that they can be passed on over generations. I would personally find it very interesting to find a way where a 15-year-old car doesn't come across as old, but somehow, it's still attractive.

And internally you would hope that the development processes speed up significantly, so that it doesn't take 4 1/2 years to develop a car, but only two to be able to react quicker to demands. That would be the second one.

So first one is on the design and acceptance of a certain product over lifetime and the other one would be speeding up the R&D processes.

Annelie Sophie Steinbrenner

OK, perfect. Alright, that's it for my part as well. Thank you so much for all your valuable insights. It helped a lot.

Umm yeah, I think I will give it over to Lena again.

Lena Maria Pertz

My first question would be what you think is the essential difference between a linear and a circular business model.

CP

The essential differences are bitter, everyone wants a linear business model and no one wants a circular business model, so that's bitter, because sometimes trying to describe, in my opinion, the circular business models need significantly more foresight, so the planning horizon is longer than that. In the linear business models and depending on the type of company, size, shareholders, structure and how the management is staffed, the incentives have comparatively short cycles and thus makes it difficult, so if you think in 6 quarters, then it will be difficult to break up the entire year from the business model. Circular, for example, with a planning horizon of 10 years. So, that is, to answer the question simply, the required foresight and doubts also the complexity of the business model, are the 2 biggest differences.

Lena Maria Pertz

Ok, and you had already mentioned that a little bit, that the transformation from linear to circular business models is then more difficult, right?

CP

That is the most difficult. But what you can see would be basically 3 different typologies, either I have a startup, which perse already starts with a circular model and can be financed for the idea, the second would be I have a company that has made money for a long time with a linear business model, has also continued to make money with it and more or less from the cash flow the life of another model, i.e. the The second stream as a circular business or the third option is I stay the way I am and only do linearly.

Lena Maria Pertz

Do you see a tendency that many companies are now slowly trying to achieve this transformation or is there still resistance to be found?

CP

You would have to differentiate between segments, i.e. industrial segments. My biggest insight into the automotive sector, which is why I keep coming back to automotive. Now I'll have to see how this is seen in your context. Before Corona, I had the impression, but then subjective impression, that companies had enough money and foresight to tackle long-term things. With Corona, everything suddenly went into crisis mode because my supply chains completely collapsed. Companies had to react much faster. And that's pretty much my subjective perception that the projects or the activities that support circular business models have been put on the back burner. Unfortunately, the last 2 years with the war have not contributed to the fact that the situation has changed, so that is my basic impression. Nevertheless, there is a driver in the context, which is regulation, so look at it and then you have to differentiate exactly from when is a business model circular and at what point did I simply implement recycling legislation?

Group Part

480 Monument of the straw over the Capri Sun for example or disposable, cutlery, specifications
481 and in recap for coffee to go is it already a circular business model or is it a substitute for
482 waste? Although that's what I'm getting at, the regulation is independent of whether
483 companies have other problems over which I don't know.

484 Of course, the power has to accelerate the transformation, because the company all at once
485 has to think of straws for example I don't know - Starbucks what the coffee mug cause in the
486 year ne?

487 But that would be the answer to too general readiness, which is interesting is the startup
488 environment. What I always find interesting, are companies that actually have a foresight?
489 In Germany, I find Lidl interesting, Lidl why?

490 Because they have started to develop further in the value chain of plastic bottles, for
491 example, with I think prezero means the disposal company, has quite a controversial
492 commercial with Günther Jauch at the beginning or middle of the year to address it? I had the
493 impression that those who had the courage. To think more broadly, if you look at the whole
494 thing now in the automotive industry, there is on the topic of circularity right now, that the
495 HV batteries, i.e. the batteries of electric vehicles, topic, there was a lot of fuss 5 years ago,
496 that has become quite quiet.

497 And I think so Second Life approaches has none for batteries, none implemented on a large
498 scale, there are always a few pilot projects, but that you say, I'm going to drive my old
499 BMW i3 back to the dealer now and the power out there stationary storage of the not so d.

500

501 **Lena Maria Pertz**

502 Ok okay, that's interesting. That's not something like that yet, I'd say, if we were to look at
503 the value chain of a circular business model now, I'd like to share a slide very briefly, where
504 that's a little bit. Maybe you can look at it together at the moment.

505 That's exactly what we've seen before, and for my master's thesis, for my part, I'm looking at
506 the value chain and especially looking at the areas that are differentiated from a linear
507 business model. And on the next slide I have the main topics that I could filter out a bit.

508 Here on the left side I have collected the Circle Business Model components and wanted to
509 ask you if you can take a quick look at it and if you think if I forgot that, so actually
510 essential Circle Business Components, which I may not have yet. I've listed here if you
511 notice something, if you notice something, yes.

512

513 **CP**

514 About by-products, we have a good consulting project, for example, if you use the waste
515 heat from kilns to supply the adjacent swimming pool or something, also you can make
516 something out of it that fits. The 7 is a bit stuck.

517

518 **Lena Maria Pertz**

519 Yes yes, that's actually a little bit of something that I've filtered out a little bit now, that's
520 totally important in the whole research, in that I've done so far that the customer, whether it's
521 B to B or B to C, is always involved, so that the customer always has the option to I'm
522 going to tell him producers of a certain product, this is what it looks like and that's how we

can co-create. I had a bit of the feeling that was particularly important. In a circular business model. I don't know what your assessment is.

CP

Definitely, that's actually one of the biggest enablers or non-enablers. Tu need, let's say, a kind of stakeholder cooperation within the value chain, i.e. between the one who does the project at the end of the consumer versus suppliers in various stages, which means that I would think of it less as two-way communication is too limited in scope in my eyes.

I'd rather bring the co-creation idea into there or the ones that see the need for steak hollow collaboration. After all, we had an example with a gearbox manufacturer, for example the OEM, i.e. car manufacturer, wanted to have remanufactured transmissions.

Gearbox manufacturer could do that but has to talk to its upstream suppliers about it, so you already have a good aspect of increased coordination needs, so you need to work together in the supply chain, especially if, if if the use then I have if now here linear business and circular business trigger conflicts. Think of the gearbox manufacturer, he will of course rather sell a new gearbox for 10000€ than a recycled one for three and a half thousand euros, which means that you sometimes have certain conflicts within the stakeholder groups.

Lena Maria Pertz

Mhm yes, I'm actually closed now, because I mentioned communication with the Custom One Company, because I know that Lena also looks at the topic in detail and I only wanted to focus on the customer, so to speak, and not involve other stakeholders of the opportunity, so to speak. But let's see if I leave the point out completely or call KO Creation between Custom and Company.

CP

Everyone there then leave the 7 in and build in an 8, where one is then in the direction of the consumer and the other is up the value chain. That would be then you have slain both, have already edited a bit but that should work.

Lena Maria Pertz

And then one more question, well, we're taking a close look at AI, but to what extent would you say that digitalization is important in general or could be an enabler for such business models? So I don't necessarily have to be AI, so in general just digitization.

CP

In the area of data and data transfer, digitalization is of extremely important importance. Ma concrete example, if I don't know exactly which material substances are in it, for example by repairing or old products? Yes, then it's extremely difficult, that's where it becomes at hand, so I have, that is, digitization can help in principle, data and data transparency and then next point I see with all the remanufacturing topics.

Something has to come back somewhere. This means that either old product has to be collected, which has to be sent somewhere. Collected, processed and returned to the new

customer, and there are an extremely large number of logistics processes involved. The usually make the business model difficult because it's so expensive, if AI could be used cleverly, let's say, build up distribution centers, keep logistics short, then that would be helpful.

Lena Maria Pertz

That's exactly where I've actually already had a look at something here, actually found that there are route optimisation solutions through match and clustering algorithms. That's exactly the topic you just mentioned, there are optimized routes, there are also partly looked at how the traffic is and all such parameters are included, so that you can really make it optimal, yes optimal.

CP

Look at the monument of fashion, this is not only worthwhile to send somewhere or because the value of the goods is simply too low, but also simply shredded. In addition to predictive maintenance, however, I would honestly find something interesting from up selling. If you're sitting in the car now, for example, and I said yes, I'd like to actually have the latest version of this whole virtual world in here. There can then be a kind of over-the-air update like Tesla does - artificially young g remains, that is, also thought in the direction of sales.

Lena Maria Pertz

Yes, that's the same. The is in good point that you also have software over the air. To offer the customer, so to speak, completely in convenience, so then service, that's true.

CP

That's how you get waste Management. The leads you immediately to the waste rail with the designation of the with the designation of the name, but in German would be something like that, if now think about waste heat, for example, AI can actually use in climate simulations, if you think you could poach it, give it to the surrounding community. But when it's 30 degrees outside, it doesn't need any waste heat.

But that means in the evening, which means that production could be optimized to the point in time when the heat would actually be needed, as waste heat, as production control

Training and Consulting. But how about behavioral change?

This is the third time I've had my jeans repaired. Actually, that's through but I don't see buying a new one. Yes, which always as a consumer just doesn't have a every half year new i don't have your 2 jeans, but so a different issue so if i now when i think about now?

Who doesn't also have an element for a business model, so I now want training or consulting, whether that fits in there now behavioral change for the customer?

Lena Maria Pertz

Yes so, I actually think so it's correct that the customer is more interested in this I don't know if you've heard of it products as a service so that you prefer this access over ownership as a customer right now, so that would be a little bit in this Sharing Platforms,

609 Rent ing, leasing and subscription in it and would then reflect a bit of the customer's
610 behavior.

611

612 **CP**

613 That could work. Alls the one thing is that I had in training and consulting I had thought
614 more about change. In the case of the customer, it says, there was a Dutch jeans brand that
615 also had a subscription model for jeans.

616 It would be interesting to see if they would have survived. You have to take a look at
617 recycling Holland jeans.

618 Unless, of course, you go into the topic of AI advertising, sensitization, customer and take
619 them away from maybe even a topic, ne even honestly really bitter.

620 Theoretically, the whole AI would have to try exactly the opposite, motivating the customer
621 to consume more or the social media user to consume more instead of consuming
622 responsibly.

623 Yes, that's a steep hypothesis.

624 The use of AI reduces the likelihood of circularbusiness models by 40%. Yes, tell me, it
625 definitely could be very powerful. I'm in direct contact with customers and communication
626 and now have chatbots.

627 Here, where, which is interesting during customer communication, when you get the direct
628 customer feedback much, much faster to where it makes sense, i.e. either to the developer,
629 just where it should go, in order to have an impact for CE, i.e. for such a business model. So
630 speed, would be my point here.

631

632 **Lena Maria Pertz**

633 Mhm yes, that's okay, yes, that's important, yes, I have to take a closer look at how it works,
634 because I think there are also extremely complex data infrastructures there, are there already
635 solutions? But there is, from a purely theoretical and hypothetical point of view, probably
636 the best approach would be to integrate the feedback so directly, that's true.

637

638 **CP**

639 But it was quite handy when I did the so yesterday we had one of my clients sent 7 pages of
640 CHATGPT. But if now the customer, let's say, who has no idea what is supposed to develop
641 a sports bag, in which engineer somewhere types in, what do my 7 customers want to have
642 to sports bags? And he has access to this information, without actually having asked it
643 directly, it would already be an enabler.

644

645 **Lena Maria Pertz**

646 Extremely, yes, totally just to have a centered database in which you can then ask certain
647 questions, whether I don't know product design or process design, yes, that's definitely a
648 giant in enabler, that's true. Exactly, but otherwise. Are these my ideas so far , I think? If you
649 can't think of any other use case now, would I actually be done by now?

650

651 **CP**

Group Part

652 That's good, let's listen together. Does it have to start with the basic question Does it have a
653 positive or negative influence on the spread of circular business models? I suppose you are
654 working under the hypothesis that AI has a positive contribution. It should be that way, it
655 should be that way.

656

657 **Lena Maria Pertz**

658 Yes, I think so, well, I think through automation, I say, and so in general, automation and
659 process optimization, AI can or should I be able to improve or simplify any kind of
660 business model in Westphalia. That's why, I think, that's also the case with circular business
661 models, because of course it's circular. Value drivers are above all optimized or efficient use
662 of resources and I believe that AI can definitely help one of the value chain in many areas,
663 so from that point of view I believe that already and here with the use cases you have
664 perhaps also shown a little bit, where exactly it is still very theoretical and I think it is also
665 very, very difficult until companies can apply something and whether they really do it then,
666 because I have now also heard in many many interviews that partly right technical teams are
667 used or needed to implement such things, there are organizational problems, that a lot of
668 companies are very resistant to this technology and don't have the experience, or the
669 expertise because of that. I think it will take a few more years before you actually see
670 implementations of such use cases, but hypothetically, I think AI definitely has the chance
671 to accelerate the circle economy.

672

673 **CP**

674 Yes, yes, I agree, it's exciting to see how the different speeds, when looking at dynamics in
675 AI development, versus the longevity, the conversion of business models, yes, these are 2
676 worlds of speeds that meet. It would be nice if one speed would accelerate a bit, the other
677 slowly. That's let's see.

678

679 **Lena Maria Pertz**

680 Yes, that's probably true, it's a certain challenge, because I think I'm going to develop more
681 and more relatively quickly and we probably won't be able to keep up with it, according to
682 the motto that then. That's it from my part and I think in general for the whole interview.
683 Thank you so much for your time and your valuable insights. I will hand over to Lena now.

684

685 **Lena Sophie Thielmann**

686 Yes, also from my side. Thank you very much for your time. I would stop the recording
687 now.

Appendix D2. MH's interview transcript

Annelie Sophie Steinbrenner

Then I would suggest that I start the introduction round very briefly. As I said, we are three students at the Nova School of Business and Economics in Portugal, Lisbon, and we are currently writing our master's thesis on the topic of how AI can improve or accelerate the circular economy. We have chosen 3 specific topics and are each writing an individual part on them. That's why we're happy to discuss all 3 different topics with you today. We have already provided the topics in advance. I think that's enough for the intro for now. If you have any specific questions for us, please feel free. We are of course ready to answer everything.

Otherwise, I would suggest that you maybe just introduce yourself to us and tell us a bit about your background, why you are an expert in this field, et cetera.

MH

I'm happy to do that. I'm originally from Aachen in Germany, but I've been living here in Helsinki, Finland, for almost 20 years now, over 20 years. I spent 16 years of my life at Accenture, one of the big management technology consultancies. I started in software development, but very quickly switched to management consulting, management strategy consulting and worked on various technology and business strategy projects. Over the 16 years initially in Germany but most of the time here in Finland. My focus was strongly on topics like Net communication, Media, and Technology industry, but also other industries in Germany, Finland, Europe, America, and Asia.

I left Accenture 7 years ago and founded my own company. Together with 3 friends/colleagues, we set up a consultancy that focused on strategy, digital technology, and sustainability, particularly in the circular economy. I was a partner and co-founder of the company for the first 5 years and worked a lot there, especially at this interface between the 3 topics, together with various companies.

I switched to VTT two months ago. VTT is, I think, the equivalent of Fraunhofer, I guess you could say, a state research institute. It's the largest in the Nordic countries, and as Lead Sustainable Business I'm now responsible for, what do you call it in German, science transfer. In other words, how can the results that our research teams produce in the areas of systems, policy, circularity, etc. actually be implemented in real life. In other words, with companies and public organizations to scale up the impact and increase the impact that goes beyond research?

Did you ask why I am an expert? I would never call myself an expert. Especially after the first 2 months at VTT, I keep realizing how little I know about the topics I thought I knew a lot about, because that's where the real experts are. But of course, I've done a lot of work on the subject, especially in the last 10 years. Also, with the topic of how can digital technology accelerate, influence and enable the circular economy and sustainability? And I would therefore describe myself as a knowledgeable person, so I have a certain amount of experience in this area, which I hope I can share with you today and which we can talk about.

44 **Annelie Sophie Steinbrenner**

45 Yes, perfect, so that sounds very good and this interface, knowing someone or being able to
46 talk to someone who knows their stuff, is great for us, as we have already noticed in the past
47 that there are many experts either in the AI area or in the Circular Economy area. But I don't
48 think this interface is that well known yet, is it? Which is why we want to write our paper
49 about it.

50 Then I can jump straight into my topic. As I said, I have also prepared a few slides, so I
51 would just share them. My research focus is a bit of a design focus: Can AI improve or
52 accelerate the design of circular products? These two circles: Circular economy and artificial
53 intelligence, and then we all have a third extra. In my case, product design.

54 I've already done a bit of research and came across this framework on the circularity of
55 products and specifically on design approaches. I would now like to know a bit about your
56 assessment and, from a theoretical point of view, how these 8 design approaches for
57 maintaining the circular economy can be classified in terms of the importance of the circular
58 economy or where you see the greatest potential. Or whether you have already stumbled
59 across them somehow in your past, in your expertise.

60

61 **MH**

62 With pleasure. So circular design is a topic that we have dealt with a lot, because circularity
63 basically originates in the design phase. If I don't design with circularity in mind, then I
64 won't be able to achieve it later in the life cycle of a product. This means that the topic of
65 design is very important. That's why it needs to be considered and looked at.

66 The 8 areas - I've looked at them before, you shared the slides - are the same as what we
67 used in our context. There are these R strategies and this framework that you are recording
68 here also adheres to them. So, it's very much in line with that.

69 The issue of recovery is always the lowest priority in our way of thinking, in our approach,
70 in terms of hierarchy. That is the last thing you should consider. So basically, you should
71 focus on long and extended use first. That means a lot of repairability, longevity and all
72 these components.

73 As a starting point, the areas here make sense, are in line with our approach and are a very
74 important topic that has a huge impact.

75 From our experience, and we have done several projects in this area, design is a topic that
76 affects many different functions in the company. So circular design is not just something
77 that should be considered in product development or in the design team, but it also affects
78 procurement and purchasing, it affects sales, but then it also affects service and so on and so
79 forth. All areas are heavily involved, which is why we have often noticed that this topic is
80 defined too narrowly in companies, i.e., as a topic that only the R&D department has to deal
81 with. In other words, product design. We've done some projects with companies where
82 we've said that we need to get the whole company involved, because the change must
83 happen on three levels - on one level, and you're looking at the technological level, which
84 means the technology has to be there. The second level, however, is acceptance within the
85 company and the mindset within the company, which is very important. And the third level
86 is acceptance and the mindset in the market.

That's why I think it's good that you're talking about design for emotional durability here. Because ultimately, it's not just about can I use the product for a long time, but do I want to use the product for a long time? And these are three levels that have to be considered in parallel.

At this point, should I also say something about AI in this context or do we want to get to that later?

Annelie Sophie Steinbrenner

I have another question first. Just as you mentioned it, let's go back to the subject of long use. I've already spoken to various companies, and they think that would be the ideal situation, but unfortunately, it's very unrealistic because it's simply not possible to create a product in the consumer electronics sector, for example, that lasts forever. Could you tell me a bit more about this? Perhaps from your experience applied to the different industries? Are there differences in the approach you choose, depending on the industry?

MH

Many companies have a lot of excuses as to why things can't work in their industry. I read a very interesting article yesterday. About fast tech. That was the first time I'd really heard the term. I had heard of fast fashion, but I had never heard of fast tech. I don't know if you have an iPhone. I come from the time when you had a Nokia, and you could go to the nearest kiosk and buy a new battery when the battery stopped working and then you replaced it yourself or you could open the phone and replace other things yourself. So back then, the Nokia was built for recovery and extended use. At some point, Apple then said, well, we're going to make the thing so tight that every time you have to replace the battery, you have to break the front screen and break a lot of other things. And that's why it's often not worth repairing. That's why I firmly believe that the concept of longevity and extended use is possible in all areas. However, we have to think differently in different areas, i.e., in different areas I have to think ok, how can I repair a product to make it usable for longer? In other areas, on the other hand, as you have said very nicely here, the question of how can I keep the product attractive for a longer period is more important? In other areas, I have to think about how I can make the product suitable for reuse. Or how can I set up a second-hand market? These are all different perspectives.

There is this nice example: when I buy a car, I think about the resale value of my car. Well, after 2 years I now have to sell the car, is the resale value great? I don't know how often you thought about it when you bought a piece of clothing or an electrical appliance, what the resale value would be at the end of its life cycle? We just don't talk about it anymore, or we very rarely talk about the resale value of smaller products or non-capital products. That's just something that companies have to think about. How can I create this second-hand market? How can I create the extension of life? Beyond the actual product design? That's why the question is often not what about the product design alone? Instead, I have to look at what the business model design is at the same time. You have to think about it together. I can't just say I'm going to design a laptop and then the laptop has a certain product design and that's

very clear. Instead, I have to say ok, I'm doing the product design for my laptop, but at the same time I'm building a service ecosystem. I read today that Patagonia has just opened its second repair center in London for its products. That's something, of course, because then I have to think about what additional services are in my circular product design at the same time.

And that often varies depending on the industry. Which product I think about, which service I think about, how I approach the topic of product design or expanded product and service design differently.

Annelie Sophie Steinbrenner

All right, well, I've understood.

I think we'll get to the whole topic of the business model in a moment with Lena. Then I would now jump to my last question and, as you have already mentioned, how AI fits into this whole system. Or rather, where exactly in this design framework you see AI potential and perhaps beyond that in the design process in general.

MH

Yes, there is a lot, and there is certainly no all-encompassing list. I think there are many different starting points.

One starting point is to really actively support the designer. So basically, using AI in the design process. That the design tool actively suggests, based on material information, based on usage data etc., which material can be used, which material has which environmental impact, be it CO2 balance, be it biodiversity impact, be it freshwater impact, be it whatever. That's one thing, that AI is really actively used in the design process.

The second is the collection and implementation of usage data. What we very often see today is that there is no direct feedback loop from the usage phase to product design because it is simply incredibly difficult to collect and then process usage data. This means that the product designer often designs a product, which then goes to the customer at some point and then the product designer doesn't hear much more about it, unless they do a focus group where they ask people. But of course, AI offers the opportunity to collect a lot more data and make it usable, which can basically be fed back to the designer via a feedback process. This is followed by the whole issue of product passports, which is also currently being discussed at the EU level, i.e., digital product passports. Digital Product Passports are currently being discussed for electronics and textiles. There are also efforts to introduce this in other areas. Of course, this is also a major topic where AI and data in the broader sense play an important and major role. How can I really track and utilize the end2end lifecycle of a product or material from the time it is taken out of the ground to the end of life and then back again? Ultimately, this will not be possible without AI because it simply involves such a mass of data at this point.

These are perhaps 3 starting points.

Annelie Sophie Steinbrenner

Yes, one more question. How do you see the topic of prototyping and the digital twin in this area? Would you also include this in design, or would it be more of a business model? And where does it fit into your 3 subcategories?

MH

So, for me, Digital Twin is in the feedback loop in terms of design thinking. Digital Twin is more in the use phase. For me, a digital twin is more necessary in the design phase as a feedback loop, so that I can see how I can classify certain feedback points and make them usable. So, for me, that would basically be a tool that was used in this area.

Annelie Sophie Steinbrenner

Ok and prototyping then probably to directly support the designer, i.e., to make the testing phase even more efficient.

MH

Yes, genua. Exactly. Exactly.

Annelie Sophie Steinbrenner

Ok, I got it. Super interesting and very, very helpful and really, really gained a lot of new insights. But I don't think I'm going to take any more time away from the other girls. So, I would stop sharing and then just hand over the floor to Lena Pertz.

Lena Maria Pertz

Yes, of course, thank you very much, Annelie. Hello [REDACTED], I'm Lena and I'm also a team member of Annelie and Lena and I'm actually dealing with the business model, so it's a good starting point that we started with Annelie and looked at the product designs. Because, as you said, if the product design is made circular, it would of course also be optimal if the business model is adapted accordingly. And the certain services or product service in general is also a big topic, because more is established because of it, I would also briefly share my slide, unfortunately I had not been able to attach any, but I still prepared something and show it briefly. Perfectly exactly, so for me, the thing is the product, so to speak, which is exchanged with Business Model Innovation and my Yes research question, so to speak, how can A I optimize, improve, accelerate the Circle Air Business Model and for this I have looked at the 5 different Business Models, among other things. That's currently in a circle economy out there and so a bit of thought ok well, which components are different? To the linear business models, which are of course extremely different and also good that they are different and so I thought about how these business model components can be accelerated by I as I said?

And there I would go directly to the next slide, if here I have already tried a bit to write out, what so. Yes, characteristics are a Circle Business Model and maybe you would like to read through the one on the left side, whether you agree with it, so to speak, whether you see any points that could be added? In terms of the Circle Business Model, components and just tell us a little bit from your point of view what you consider vascularity in the business model.

215
216 **MH**
217 Well, right off the bat I wouldn't be able to think of any additional element, I might have to
218 think about it a little bit longer. But basically, the business model is about, as we have just
219 talked about, keeping the product in use for a long time as possible and then also regaining
220 the resources. In my last job at Thai Wahl, we developed a circular business assessment
221 together with WWF Germany. This would also have been done for some companies, for
222 example with BASF with Schüco Group with Otto Group and so on. And which is often the
223 case when you talk about circular economy with this company, then the approach gets loud.
224 Well, we have to regain the resources at the end. And to redeploy the resources, that
225 basically means to say ok, I have a business model where I get my product back at the end, I
226 can disassemble it and then and only then use it again. Topics such as manufacturing and
227 also the use of components are often missing and that's just a point, I think that was the Co
228 of Peugeot, who once said that our remanufacturing plant is the most profitable we have,
229 because we can basically sell the remanufactured products for the same price, like the new
230 products but the entire production process is eliminated. In other words, from an economic
231 and business model perspective, it makes a lot of sense, but it is often not taken into
232 account.

233
234 **Lena Maria Pertz**
235 For what reasons exactly is remanufacturing usually not taken into account?
236

237 **MH**
238 There are several points. On the one hand, when talking about circular economy, the first
239 thing most people think of is recycling. Yes, I'm already doing recycling and that often
240 happens when we go into companies and talk about circular economy, and say yes, we're
241 already doing waste separation, we're already doing waste separation and and we also
242 get our products back and recycle and say yes, okay nice first step but there's the garbage,
243 Hierarchy and different approaches that you can do in the field of circular economy, so on
244 the one hand there is really a mindset and understanding problem of what circular economy
245 really means. The second point is complexity, it's often much easier for companies to say,
246 we restore the raw product and then go through our normal production process, because we
247 look at metal, for example, then I think the metal recycles the metal and then there are
248 friends back in a production process and the production process ultimately doesn't have to
249 change. But if I do refurbishment or if I want to add certain components to the process flow,
250 I have to adapt my process accordingly. In other words, I've been dealing with complexities
251 not only in my own operations, but across the entire value chain. Because I often have to
252 involve other partners within the value chain and this complexity is very often very difficult
253 for companies to address and manage, which of course brings us back to your topic very,
254 very quickly, where AI and certain approaches can and must help to address these points, so
255 how can I model and then manage this value chain?

256
257 **Lena Maria Pertz**

Mhm yes, but you just said that this generally brings a complexity with it. Circular economy and a lot of people have a wrong understanding of what is really circular, don't you think in theory that AI brings complexity to it? Because so many people don't know exactly how they can use AI correctly in their companies, which then brings additional complexity with it, at least at the beginning, before the formal frameworks have been set.

MH

Ja absolutely right, and you say you just said exactly the right thing at the beginning, I think we have to differentiate here between the introductory phase and the operationalization phase, in the introduction phase, of course, it brings additional complexity, because I don't just have to understand circular economy and I have to understand AI, then AI is not the same, so when I talk about there are also very different approaches very different tools that I can use in the area AI. There are certain complexities in the range from very simple applications, which are more reminiscent of the database, to very complex applications of AI in the context of the introduction. We have talked to BASF and BASF says yes, we would like to make a circular economy, but we are at the beginning of the value chain as a company, we produce plastic granules. The overall complexity of take-back systems, of integrating a product back into the value chain through 'reverse logistic' operations, can be significantly reduced with specific AI solutions.

Basically, how are we supposed to manage the end-to-end supply chain and then retrieve the product at the end? To recycle it in a mechanical or chemical recycling process and then bring it back into our process? We have, we have this understanding of the value chain in both directions, we don't have it at all, we may still have a contractual relationship with a 2 suppliers or with a customer. But we don't have that end-to-end understanding at all, so we're talking about the Digital Passport Product Password.

In order to be able to somehow map and say exactly these complexities, I like to say how do I manage this feedback loop at all, which so far very few companies really understand and can manage at all, especially companies that are very much at the beginning of the supply chain, and that's where business business models become very difficult. We are currently working with Mezzo, which is a company here in Finland. They make machines for the mining industry and those who also work very the topic of circular economy. They're just saying, well, well, we have our wearables and our use parts, they're somewhere in the world, no, they're in South America, they're somewhere in the mines of this world. How are we supposed to bring them back, how are we supposed to make a circular model that doesn't negatively affect others on the other hand? Impact generated? So at this point, there is a great deal of complexity in this context, which then prevents a lot of companies from ultimately saying, okay, we're going to tackle the topic, and we're trying to try to understand it at this point.

Lena Maria Pertz

Yes, yes, definitely one last question, maybe about business model innovation, so of course there are a lot of business models that still drive in linear what would you say? What is

easier to apply in already existing business models, which then become more circular or set up new business models, so to speak, startups, so what is your experience in your opinion?

MH

At the moment, there is a problem with circular business models with or without AI. In terms of scaling, this is the one that is very difficult because very often the economic component is very difficult but is no different for district administration than it is for others, for other startups or for other innovation ideas. Scaling is very difficult, in principle, regardless of whether it is AI or not. That's now, that's more of a feeling now, so I don't have a database for now, I think it will be easier to integrate into new business models than into existing ones. Simply because the resistance is also lower, because when I develop a new business model, I work with the innovation team on the new business model. Business model if I want to integrate into an existing business model then I have to work with my production people, then I have to work with my supply, then I have to work with more stakeholders along the supply chain to implement these changes. That's why my gut feeling is that it's easier to develop new business models with AI.

Lena Maria Pertz

Yes, that sounds reasonable. That was it for my part actually, and now I would hand over to the other Lena. Thank you very much for your insights and your time.

Lena Sophie Thielmann

Thank you also from my side for taking the time today and I would start with sharing my screen.

I don't know if you had time to look at the barriers before and at what we sent, but we just came across the topic of complexity, i.e. how can we really manage the circular economy in the end?

What are the issues that can be tackled directly, so to speak?

And that's where I came across the topic of collaborations in the area of infrastructure and the question how AI can support and accelerate these collaborations. I structured it in such a way that I found various barriers that need to be overcome in order to realize and support the circular economy and filtered them down so that we ended up with 10 obstacles and my idea or my goal is to first look at what are really the most urgent obstacles for a collaboration in a circular economy that we are currently talking about.

Of course, you always read a lot in research papers.

But what is the current situation in the market?

MH

Mhm.

Lena Sophie Thielmann

And I would be very grateful for your insights in order to see in the second step which of these barriers AI can really address and start with. The idea is that we go through the

individual barriers and first look at what their role is in relation to the circular economy and then, in the second step, look at where AI can really help to overcome them.

MH

Yes, I looked at it beforehand.
I found it very exciting to go through the different barriers and also to try to place them on the X and y axis.
It's not easy, but it's definitely an interesting way of looking at it.
Shall we go through from 1 to 10 and I'll say a bit about all of them?

Lena Sophie Thielmann

Yes please.

MH

The temporal dynamics of technology are more about the development of the technology, or that it develops differently, right?

Lena Sophie Thielmann

Yes, exactly, and also that the current status quo of IT systems is different for the various partners, but also that developments are progressing at different speeds, as you rightly said.

MH

So I can see the problem here very clearly.
A long time ago, we spoke to Alko, the alcohol monopolist here in Finland, and one of their tasks is to create transparency about their wines and their sustainability. Then we discussed how we could present an end-to-end view of the wines. From the vine that is picked to the rural end product, where we quickly realized that a winegrower somewhere in South America might not even have an internet connection. How is he supposed to enter data about his vines into a database that Alko can then use?

This means that there is very often a serious difference in the status of the technologies in a global supply chain, which you have to cover in the circular economy because I have to work with a lot of partners, so this is a very important point. Where there is definitely an approach. Now the question is whether AI is the right technology to address this or are topics such as blockchain or similar topics more important? But I think that AI at least, I wouldn't put it on the high side, I would probably put it on the somewhat lower side, I don't know exactly how AI could play a serious role there.

Point 2: The different management practices. This is a big problem.

But in my view, they are a general problem that companies have along their value chain, as there are very different practices.

I wouldn't see the impact on the circular economy as being that high.

Yes, AI can of course help to translate and adapt the practices, so probably more on the lower third in terms of their current urgency for collaboration and then on the right-hand side.

387 Stakeholder monitoring in different contexts, company-focused, has a definite impact on
388 circular economy collaborations.

389

390 **Lena Sophie Thielmann**

391 Yes exactly, as we are talking about barriers to cooperation. Therefore, it refers to the fact
392 that companies are monitored differently in their performance and this partly prevents the
393 possibility of an equal consensus for cooperation, precisely because, for example,
394 stakeholders pursue different goals for their companies.

395

396 **MH**

397 Yes, so when it comes to targets, I saw that in point 6 as well, the mismatch of targets.
398 It's a huge problem that different parties in the supply chain have different goals, incentives
399 and operating environments when it comes to this. This is a huge problem in the circular
400 economy, because companies are of course optimizing themselves in many areas.
401 I would say AI can of course help here, so I think the positioning is already quite good,
402 perhaps a little further to the right, but not on the high side either.
403 The loss of information I believe, and this includes the question of information processing,
404 because the problem is often, as I have already mentioned, that the amount of information is
405 often so large that it cannot be processed and that this results in a loss of information.

406

407 **Lena Sophie Thielmann**

408 Exactly.

409

410 **MH**

411 This is a problem because, of course, if I want to take a phone apart at the end of its life, I
412 need to know what materials are in it, or if I want to dismantle a building, I need to know
413 exactly what has been done in this building. In other words, there is a big impact on CE, and
414 I think AI can also help a lot to address this. For example, by prioritizing and collecting
415 information and then processing it at that point.

416

417 **Lena Sophie Thielmann**

418 Do you think that the status that AI has today could reach its limits if you think about the
419 really diverse partners that would want to work together, such as public institutions with
420 private companies, could AI reach its limits in a certain way in the current context?
421 Or do you think AI is still very, very well positioned in this regard at the moment?

422

423 **MH**

424 It's a difficult question because, of course, it's often about what questions I ask and then
425 that's a completely different discussion.
426 The topic of AI is also a completely separate, stand-alone issue.
427 Today, companies often go in and say: we collect all the data and then we simply ask what
428 the data can tell us, which is of course a completely stupid question. Collecting all the data

in the entire company and then saying the analytics team will go and get something great out of the data, which simply can't work because you have to ask specific questions.

So I don't think the quantity is such a problem.

Furthermore, development is progressing very, very quickly at the moment. Be it in the field of supercomputers or quantum computers, I don't think we'll reach our limits any time soon. The problem from my point of view is point 5, which is an incredibly big problem.

We held two series of events some time ago. One was called "AI-Monday" and the other was called "Digitally Circular" to address precisely these digital and circular economy topics. And then a startup founder came to me and said [REDACTED], you know what? Someone told them, well, they're using AI to scan X-rays and things like that for signs of cancer. And someone told the hospitals how valuable their data is. And they are now saying we can't give you our data for your use case or for your test because our data is too valuable. But it's just sitting in the basement on some server and nobody uses it, but it's so valuable, you can't share it and that's just very common. It's a combination with the fear of losing your own data or allowing someone else to use your data is a huge problem at the moment. That's why I just mentioned what we're seeing today. Particularly in the area of the circular economy along the supply chain, many companies only really have contractual relationships one or two levels deep, meaning that I can go to a direct supplier A and say, you give me your data now, otherwise I'll look for someone else to become my supplier. But 2 to 3 levels down, I no longer have this leverage.

In other words, I basically can't collect the data along my value chain because I have no basis for collecting and processing this data.

In other words, at that point me as a company starts to say that 'it is also valuable for you to do this' or 'don't you want to give me your data because we all want to do something good'? As a result, this data is very often not available because companies do not share this data and do not use it. Today, programs like Gaia x from the EU say that we need to find a neutral partner to mediate between these companies. And they then bring this data together and what you can imagine in the future is that this is not a party, company or organization, but that AI can take on this role of data collection, data anonymization and analysis. And then only provide different parties with the data that they have access to. So AI, used correctly, can make a good contribution to collecting and then analyzing the data. To counter this fear that I can't share the data or my data will be lost.

Lena Sophie Thielmann

Okay, that means that the topic of regulation would actually still be an essential obstacle that would have to be included, wouldn't it?

MH

Regulation is a huge enabler for the whole topic of the circular economy, if we for example look at the gruenepunkt in Germany or the deposit system for bottles and cans. That would never have happened if people had said, "Dear company, do something good and reuse your resources". It only came about because the legislator said either you take part in the green dot or you pay taxes.

472
473 **Lena Sophie Thielmann**
474 Yes.
475
476 **MH**
477 That's why regulation is a huge enabler in this area. But it's definitely creating big problems
478 for a lot of companies at the moment, because there's just so much at the moment.
479
480 **Lena Sophie Thielmann**
481 Yes, that's right okay and then at point 6 there was actually already a certain similarity to
482 point 3, which means the importance is definitely there.
483
484 **MH**
485 Exactly.
486
487 **Lena Sophie Thielmann**
488 That's a huge problem, especially in terms of collaboration, that the goals can't currently be
489 coordinated, right?
490
491 **MH**
492 The goals cannot be aligned and of course there are also other goals. However, this doesn't
493 just have to do with the industry, but also with the type of company, for example. If I am a
494 listed company, I have different objectives than if I am a family business or a start-up.
495 Accordingly, it is very often difficult to reconcile these objectives. But I don't think AI can
496 really help here. It's a long-standing problem between start-ups and large companies and AI
497 hasn't really helped yet.
498
499 Lack of standardization is a problem because the data flows between systems are not given.
500 Companies such as SAP and Microsoft are currently working very hard on this.
501 Incorporating topics such as Co 2 and other Impex into their systems is definitely a problem
502 where AI could then also function as a translator.
503
504 The next point is risk management. I wouldn't see this as such a big problem, to be honest.
505
506 **Lena Sophie Thielmann**
507 On the grounds, so to speak, that it's standardized these days, right?
508
509 **MH**
510 Of course, it depends on what we mean by risk management. Risk management approaches
511 are of course very different, depending on the company. What we often see is that one
512 company says resource scarcity or resource availability will be a huge problem for us in the
513 future. The other company says no, I can deal with that. Schüco, for example, told us that
514 their customers are currently asking for recycled aluminum. But they can't get any recycled

aluminum because the automotive industry is currently buying all recycled aluminum from the market, which means they have to think about how to deal with the risk that we will no longer be able to meet our customers' needs. However, this is not necessarily due to the fact that there are different sectors. It doesn't necessarily have anything to do with the cooperation, but with the company's internal interpretation of the risks, which are often different. Which is why there are other perspectives, but I wouldn't really see that as an obstacle to cross-sector cooperation.

And point 09, can you perhaps explain again what exactly would be the obstacle to cooperation?

Lena Sophie Thielmann

Yes, exactly, so cross-sectoral cooperation is really intended in any direction and especially with regard to developing countries, which today have the focus on generally participating in economic activity and are often used as landfill etc., currently do not have the need to participate in something so sustainable and also do not have the resources to participate in something like this, which in itself limits cross-sectoral cooperation again, because you are trying to build a complete system in the circular economy, so to speak.

MH

Of course, this goes a bit in the direction of what I mentioned at the beginning, the winegrower in South America does not have the technology and cannot afford to invest in this technology. Which is why I see it as the responsibility of large European companies or large global companies to build this infrastructure. That means that yes, it does exist. Especially with developing countries or emerging economies. But even there I don't necessarily know how AI can help, because I need the technical infrastructure anyway.

And inflexible policies and structures are a huge problem, especially when it comes to cross-border cooperation. Here, too, the question is what could AI do? At this point, it is perhaps a bit similar to what we have just discussed to ensure that only data that can really be shared is shared, so I would perhaps classify it as something in the middle. At the moment, a lot is happening at a political level when it comes to the circular economy.

Lena Sophie Thielmann

Great, thank you very much for sorting that out. One very brief final question from me, is there any obstacle that you are missing here in the presentation. We've just touched on the subject of regulation, but have decided that it's more of an enabler to overcome these barriers. If not, that's perfectly fine, of course.

MH

So there are two points, one is the different level of knowledge of the employees. It's a huge problem, that's what we're seeing at the moment. We are currently working with ENBW in Germany and what they say is that when we work with our suppliers, but also with mezzo, the same problem was that they say when we work with our suppliers, we first have to

explain to them what the circular economy actually is and why it is important and what it means for them. In other words, it's a huge problem that you basically don't have the same vocabulary, you don't have the same level of knowledge in different organizations and therefore you discuss different things. The second is the strategic priorities of companies. You have a bit of that in here with management practices, but it goes one level further, so what really is the strategic direction? The strategic priority we often talk about is the circular ambition level. Because, of course, various companies say that we need to focus on all the sustainability issues. We can't hire 150 people to work through all the sustainability issues and different companies set different strategic priorities in this context, which can of course differ. If one company says we are doing CO2 footprint reduction and the other says we now want to do resource efficiency, then they are different. They both contribute, but they have different priorities and that's why they don't really get on top of each other.

Lena Sophie Thielmann

Yes definitely 2 very good points, thank you very much. So that we don't go any further over time. As a final general question, also in connection with the other two areas, is there perhaps any insight or anything else you would like to share with us?

In connection with the circular economy and AI, any points or approaches that you are currently observing there that we should perhaps take up a little further.

MH

First of all, thank you for the interview. I found it very interesting and very exciting to see your perspectives on the topic. The perspectives you have presented here are very, very interesting. I have a bit of a feeling that I've mixed you up and thrown different topics into the mix.

In principle, the topic of data as a basis, which AI is based on, is a huge topic in the circular economy at the moment. Because it's about material flows and I need to understand how these material flows behave across company boundaries and geographic borders. This means that it is often not a problem of AI that we are talking about, but rather a problem of data sharing or data collection, of data availability, on which the problem of AI is then based. In other words, the issue I mentioned of collecting data along the value chain is not an AI problem once we have the data from the wine farmer in South America to opening a bottle of wine on the sofa in the evening. Then we can put AI on it and understand where we can make certain optimizations, where we can do certain things along the value chain.

The second issue is utilizing AI correctly and that is the other component. AI, and I've been working on this for the last 20 years, is not something that has only been around since yesterday and at some point everyone started saying AI can do everything, just tell me your problem and then AI will solve it. But from my point of view, AI is able to deliver the best solutions when I have a defined problem that I want to solve. I have a very narrowly defined problem that I want to solve and generate the appropriate approach for it. In other words, if you are thinking about AI in the context of the circular economy, I would try not to approach everything and say, well, let's look at how AI can do the circular economy. But to

say ok, if we look at a value chain, and I'm talking about the extended value chain, so not just what happens in the company, but what happens before, what happens after, what happens in the life cycle and then also in loop back. Where are there certain starting points, concrete starting points along this value chain?

What we have often done is we have borrowed these user journeys from service design and said we don't look at user journeys, but we either look at material journeys or in any case look at the entire flow and say where are there starting points for AI along this circular economic value chain?

Because then you can also point this out nicely and say, here are the 3-4 points and we'll take a closer look at them.

Exactly through the different lenses that you mentioned from the technological side, from the business model side, from the cooperation side and so on and so forth. That might be another point, to keep it as concrete as possible, because otherwise it's very easy to get lost in: AI can do everything and AI is the wonder weapon and AI makes the whole world capable of circulation.

Lena Sophie Thielmann

Yes, for sure.

Annelie Sophie Steinbrenner

I have a question about that. I find the last point very interesting. We've already tried this a bit by saying that we can't look at the entire value chain. We can't look at every aspect of the circular economy. But I had the feeling that you thought we were still not defined enough. Because it's still too broad, in my case, for example, product design, did I understand correctly that you could go into the individual topics more specifically in order to define these starting points?

MH

The difficulty here, and this is also something we see very often in companies. The difficulty is that the circular economy is not a topic that can be anchored in a specific area. The circular economy is a topic that the head of supply chain has to be involved in, the head of sales has to be involved in, the head of procurement has to be involved in, the head of product design has to be involved in, basically all the different functions in the company have to work together.

Plus all supply and plus all customers etc.

In other words, if I take a topic as you have now done and say ok, I'll take a look at design, then I'm not just talking about the R&D department, I'm talking about it, just like we talked about, how does design relate to the business model? How does design relate to my purchasing? How does the design relate to the end of life? In other words, the focus you have chosen still requires a very rooted consideration.

We have just seen this in the cooperation topic. It's still very complex, because we're talking about suppliers, we're talking about employees, we're talking about regulators, we're talking about all the different stakeholders that are affected by this topic of cooperation. This means

Group Part

644 that I can't necessarily easily make a ring fencing where I say, and this is what I'm looking at
645 now. And that's why the comment I'm supposed to make is that it's very easy to try to write
646 something and then realize: Oh, there's the aspect and the aspect and the stakeholders or not?
647 As a result, it can be very easy for you to get into a huge, complex context with all your
648 areas, i.e. from the business model to cooperation to design, all of which are so intertwined
649 that it is still a very big topic. Because it always depends, when I cut a cake, how I cut it,
650 whether I take complexity out of the whole topic - that's not easy.

651

652 **Annelie Sophie Steinbrenner**

653 Yes, ok, that's I think probably the biggest limitation that we've already noticed in our
654 research, that there is of course an incredible amount in this area and you can't look at
655 everything, as you said, but everything somehow builds on each other, but it's very good that
656 you said that again.

657 I think everything is clear from my side, I think Lena's and Lena's too. Perfect, then thank
658 you very, very, very much.

659

660 **MH**

661 Yes, that's exactly what I wanted to offer, so if you have any questions or other topics, we
662 can talk again. It's a very exciting topic and I really enjoy talking about it and am of course
663 very curious to see what you come up with.

664 So when you've finished, I'd love to see how you bring it all together afterwards and what
665 your perspectives are on it.

666 Great, then thank you very much and have a nice weekend.

667

668 **Lena Maria Pertz**

669 Yes, we will do that, thank you very much and have a nice day as well.

Appendix D3. DK's interview transcript

Lena Maria Pertz

Thank you very much for taking the time to talk to us today. Before we get into the topics, it would be great if you could briefly introduce yourself.

DK

With great pleasure. My name is DK and I currently live in Düsseldorf, Germany. I work at KPMG Germany and my area of expertise is EG Reporting/Circular Economy. Therefore, it is a holistic view of the topic. Starting with data, IT and IT infrastructure, BI, i.e. business intelligence, or business information. And some of these already include circular economy topics. At the same time, I also do a lot of research in the field of circular economy together with the University of Augsburg and RWTH Aachen University.

Lena Maria Pertz

We have already sent you a few materials by e-mail and we would now per topic, so each of us has taken a closer look at a topic of these 3 topics and per topic we would now just exchange a little bit with you for 15 minutes what your experiences are there and accordingly show the materials therefore exactly the 3 topics are once circular business models with which I start Will. Then Annelie continues with the topic of Circle Product Design and finally Lena continues with the topic of Cross Industry Collaboration also within the Circle Economy. Therefore, I would like to share my slide briefly, so that we can start exchanging ideas about the first topic.

As I said, I'm looking at how AI technologies or tools can optimize Circle business models and accordingly I've looked at a lot of research in the area of what business models already exist in Circle Economy?

Economy and I don't know if you've most likely heard of them too. In most cases, it is broken down to 5 specific ones.

In 7 different Circle Business Model components. I don't know, had you ever looked at the slides and?

DK

Ah yes, I got the first overview, but I had some questions about the first slide, if we could get to it, and that was the first question, so the first question would be what is AI? Of course, this is now possible.

That means, this is very clear, I have the difficulties to understand, we want to talk, because many customers who say yes, we have AI elements this and that, but reality this, in the best case, BI or simply clever algorithms, so that simply the word is simply used as a base board, so the first question would be, what is it?

And the second question would be?

Let's talk about the circulating business models or secular business mode in the proper sense.

Yes, what I mean by that is certain difference, because any business model can be made more sustainable, so yes that means you can pay attention to sustainable sourcing monkeys.

Group Part

You can extend to the product lifecycle files and so on and so forth, which is a more sustainable or circular business model, but not a classic use case of security. Or to put it another way a signed business model is the knowledge model, which would not work without circular value creation.

And a circular business model is a business model that could go on without these circular elements. And there is the question, what is, what is the focus here?

Lena Maria Pertz

Yes, so first of all to the AI question, in fact, in most cases I have now looked at algorithms yes, so whether it is clustering now, but also things like predictive maintenance, i.e. machine learning and so it is relatively broadly defined.

I didn't want to specify myself yet, because I wanted to get a general basic understanding first. How can it be applied at all?

And then in the course of the interviews and research, I would perhaps like to understand any kind of AI in this business model and to the second question, if I understood correctly, you would have asked if we are looking at pure circular business models that otherwise don't work, right?

Or Whether you look at linear business models, they try to be more sustainable, exactly - I'd be more interested in the first point.

This is really pure circle business models that have the main value proposition to operate in a circular manner from the ground up. In order to continue, so as I said, I then picked out processes from this circle business model that are indispensable in a circle up to the model. The I wanted to ask you at this point. With these 7 that are listed here, if you are still missing any one component simpler.

DK

Ok for example point 3 waste management systems. In general, it's not just about waste management, it's actually about holistic monitoring of circulating performance and there are not only waste, but product life elements, lifespan, how often something is sent back and so on and so forth.

So now we're going to move on to something more general about management systems or a management systems, controlling, monitoring and, which is also part of it now or a point general management one with management systems and a point to that would now be advances analytics and BI possibly also AI for increasing the circularity.

So one point I would rephrase, which is the third point in general Environmental Management Systems and one more point I would add, which would be directly linked to this Environmental Management System, an environmental BI and environmental Advanced Analytics and that could also be called AI.

Lena Maria Pertz

Ah, ok, understood, okay, so that would be 2 extra components to be added, so to speak.

DK

87 Mhm so 1 how changed and one will that be added?

88

89 **Lena Maria Pertz**

90 Exactly, okay, yes, yes.

91

92 **DK**

93 Because what I mean by that is when we want to improve performance in something or at
94 least maintain it. We have to measure it, when we measure something, we have to make it
95 more or less addressee-oriented, and so on and so forth.

96 And if we have all the information, the data, we now have infinite or many possibilities, the
97 advantages, i.e. in the economic sense as well as in terms of the environment, form
98 advantages e letters, for example through advanced analytics or now the term that has
99 already been coined, predictive maintenance is a very big topic now in industry and actually
100 everywhere.

101

102 **Lena Maria Pertz**

103 Okay, yes a maybe then we can come directly to the next time, because I have actually
104 already written down a few use cases that I have found, where AI is already applied in circle
105 business models and maybe again on the topic of predictive maintenance here point 2. You
106 might give it an inside on your part, do you already know of any use cases where or how
107 exactly would you describe productive maintenance and the circle economy? What is the
108 relation?

109

110 **DK**

111 So predictive maintenance, that's basically something from analytics, and that means we can
112 measure the data that collects data. We can structure the data and prepare it and draw certain
113 economic or environmental technical advantages from it, ah what that, uh, how the current
114 industry is used very different applications. So one example is factories, where not in factory
115 planning, but now in heat pumps or in factories in general, critical elements are placed, sors.
116 They place sensors, collect data, and based on the data, if you don't have a clue about
117 hundreds of millions of observations per year, you can make certain predictions. Because
118 something breaks and so on and so forth, that means that can then usually do something,
119 can a component, it can be replaced or serviced before it breaks. Materials are saved,
120 knowledge is stored, waste quantities are saved and so on and immediately and they have
121 and this application is basically the same, but at practically different industries. This can also
122 be used in vehicles. It is also often used now in the automotive industry, who is told where
123 yes this and that has to be maintained, or oil has to be changed, yes, because we are doing
124 change to prevent engine damage now and so on and immediately. So that's very, very
125 diverse along the industry as that's used, but in principle it's always very similar.

126

127 **Lena Maria Pertz**

128 Always similar yes, I have also seen that it is used relatively often manufacturing, i.e.
129 devices are sometimes also used that are given to certain customers especially in B 2B, if

for example also through leasing relationships plans, that even then there can be politics in advance, when which parts most likely give up the ghost, I'll tell you. Exactly then, about Thema Waste Management, we just had a little bit of something, what do you think about the topic of Take Back Systems are they? In the field of AI or digitalization, there are already use cases.

DK

Take Back System is something like taken back and refurbished or built on elements and then these elements are then installed in the new product. I don't think so, it's more of a design and technical topic at most in the basic text. If we look at this business model for several years now, you can use data to determine which elements will be replaced, so in most cases. So it's completely thrown away, or what elements have to be produced afterwards, and you can then practically reproduce it in advance, you know, if I send such an Apple piece back, this attachment, this little piece can be thrown away, but the rest is then kept in the cycle and accordingly this little component and afterwards has to be produced.

Lena Maria Pertz

Thank you very much for that and then I know that I have often read that it is particularly important in the silent economy that you leave the customer in the feedback loop, that co-creation happens with the customer. To what extent do you see this point, especially in the circle economy, this is an important, important aspect.

DK

Oh, that's definitely an important aspect. But I would expand on it a bit and say that it's not just customers, i.e. these, who need communication, but at the same time we also need courageous, multilateral communication between different stakeholders, but are the requirements of the customers, that's very important, like the communication or like C communication, but at the same time what are the responses of the suppliers? Yes, because you have to ask with the suppliers, you have to talk to energy, suppliers and so on and so forth, so that you have such a practically holistic, communication strategy, once bilaterally and once multilaterally all together and maybe by the way. We recently had an IOP, which would be a large corporation and says makes us an offer on a specific topic. And there was the topic They wanted to have a collaboration management system for circular economy and environmental data, because they said ok circular economy and ESG can't be solved alone. We have to talk to everyone and at the same time, and that's where we need a collaboration platform like this. It's just by the way.

Lena Maria Pertz

Mhm yes, no, that's especially important for the last topic that Lena discusses later, so it's

Group Part

very interesting. Exactly what I actually wanted to inquire about, to what extent then also, so to speak, because I actually only contact the B2B customer. Or does she offer to look at customer contact, because I don't want to rattle him into the topic, I wanted to ask if you there somehow. You have use cases of how this huge customer contact could theoretically be optimized by AI, because I have found, for example, things like chatbots or virtual assistants, which can theoretically alert the customer directly due to real-time and productive use patterns or can approach him, for example. A device somehow in the next time runs the risk of no longer working, that you can leverage something like that even with I say times.

DK

This is practically a topic that is now in the predictive analytics and predictive maintenance that they are very strongly networked because, for example, an example around a robot vacuum cleaner that tells me when the parts need to be serviced so they say now 3 more weeks, then the camera has to be moved, so really get such Notifications or in so-and-so much must the wipe rag or mop is. So if that was I would very strong link to Predictive analytics and BI and predictive maintenance.

Lena Maria Pertz

Ah, okay, perfect and so chatbots or something like that are not a traditional way to share something like that with the customer?

DK

Yes, probably later again, but now the current state of chatbots. Bots that's the sind yes great, stupid you have to honestly say that yes, so these are now practical very, it has to be a very standardized process, because with chatbot works otherwise that's just annoying.

Lena Maria Pertz

Yes, that's good to know, because that's a different opinion in itself, because I've actually heard here and there now that chatbots are used but they probably still need a certain g development to be able to give really efficient and performance-oriented input, so they're not up to speed yet, where they do a lot of value ad, you would say?

DK

Now from my own experience so with chat bots I have very little experience. Here are consulting and research now from my consumer perspective I would say that they are not that helpful now, but I may be wrong, is just my personal opinion.

Lena Maria Pertz

Okay, one final question, can you think of any use case that you have noticed that stands out where you have seen AI in relation to circle business models?

215
216 **DK**
217 I might have to think about AI in CE for a minute. Because, basically, now that you are not
218 quite there yet, because first and foremost, if you now improve CE performance by now
219 instructing also special methodological solutions, yes, for example, life cycle assessment
220 and these are basically evaluation systems on how to improve the environmental
221 performance of a product or service can be evaluated as a whole, and there are highly
222 complex procedures. You really have to be technically savvy, you have to be an economist,
223 you have to be an engineer, you don't have to have a bachelor's degree in maths so that you
224 can use this life cycle assessment. I see great potential in the application of AI in the
225 application of environmental assessment solutions. Just because at live so every product or
226 service can be evaluated and you have to evaluate that in order to quantify the environmental
227 performance at all, for example, process systems have to be put together from a lot of
228 small puzzles and if I'm not an engineer, then I don't know which process comes in now?
229 At the moment I'm working in this case, we're doing this for an excavator and if aluminum
230 comes into the company now, I don't know what will happen to the aluminum.
231 I click on this process Aluminum comes in, but I don't know what happens next and for
232 example we could then suggest algorithm, based on statistical data of the other users. Ok
233 90% of the users have this and that, so for example aluminum probably needs to be heated
234 and weighed.
235 So that all the further process goes in, that would be a so polite, helpful business case, but
236 also helpful I application for evaluating the environmental performance of products and
237 services.

238
239 **Lena Maria Pertz**
240 Thank you so much for your insights in this area is very, very helpful, also that you have
241 validated certain things already found yourself but also found yourself, but had also doubted
242 things that I found, therefore very, very helpful. Thank you very much, I would then pass on
243 the word to Lena.

244
245 **Lena Sophie Thielmann**
246 First of all, thank you very much for taking the time to talk to us.

247
248 **DK**
249 Yes, of course, I hope I can be helpful.

250
251 **Lena Sophie Thielmann**
252 Yes, totally, so what I've heard now is definitely the first proper use case that someone has
253 mentioned the topic of collaboration on their own initiative. That's why I was really pleased.
254 I looked at the whole topic of the infrastructure of the circular economy and came across the
255 topic of collaboration pretty quickly. Because exactly what you just mentioned in the use
256 case, companies can hardly make this transition to a circular economy on their own, so you
257 really have to work in a network and build new networks to make the transition.

258
259 **DK**
260 Hm.
261
262 **Lena Sophie Thielmann**
263 I thought about how AI can support this and came across different barriers in my research
264 and broke them down to 10 barriers where AI has points of contact through existing
265 research.
266 My idea now would be to simply go through the barriers and gather your opinion on them.
267 On the one hand, what is their importance for the circular economy itself and what
268 possibilities does AI have to help overcome them, also in connection with your experiences?
269 And then the aim would be for us to position them together on this matrix.
270
271 **DK**
272 Okay.
273
274 **Lena Sophie Thielmann**
275 The temporal dynamics of technologies this simply means that the various cooperation
276 partners have different IT systems in the currently existing status quo and that the
277 development behind these IT systems is also different. So I would be interested to know
278 what your opinion is in relation to the circular economy and AI.
279
280 **DK**
281 So the aim is to place them in the matrix, right?
282
283 **Lena Sophie Thielmann**
284 Exactly, yes.
285
286 **DK**
287 So I would rate the immediate importance for the circular economy as very high, the highest
288 there is. Because at first glance, the topic seems rather trivial, but in reality there really are
289 huge differences between companies. And you really always need a common IT
290 infrastructure as a basis for cooperation. In fact, most companies today don't even have their
291 own infrastructure, which means that they really do write to each other in Word files, or
292 work with Excel or completely different systems. There definitely needs to be an alignment.
293
294 Yes, and I think that's a big obstacle because, for example, if you're a bit more advanced
295 now and work with life cycle assessments in your company. These are developed in a
296 specific format. And if you send that, I can't read it in at all because I'm not familiar with
297 such systems.
298 So I would rate that very highly and the chance of AI acceleration is rather low in the short
299 term, but in the long term it's medium to high.

300

301 **Lena Sophie Thielmann**

302 Okay, then I would put 'high' here, so to speak. And with different management practices,
303 how do you see the risk of collaboration?

304

305 **DK**

306 So I would rate it as medium in terms of importance for the circular economy and the chance
307 of acceleration as low. Because basically the risk is not so high for operational and
308 management practices, as steering committees are currently being formed, where the key
309 stakeholders gather and then work together. This means that it is not an entire company that
310 has to work together with another company, but only the key stakeholders. This is
311 problematic, but not so tragic.

312

313 **Lena Sophie Thielmann**

314 Okay, I see. And then in point 3, the monitoring of performance in different contexts, so to
315 speak, focused on the companies, that stakeholders track and monitor the performance of
316 different companies in different contexts or industries differently. Which can of course also
317 be a barrier to collaboration.

318

319 **DK**

320 So, I would rate that very highly in terms of its importance for CE and the chance of
321 acceleration is also very high. That brings us back to the issue of data collection, monitoring,
322 controlling and so on and so forth. This is not yet fully developed and there is great potential
323 here.

324

325 **Lena Sophie Thielmann**

326 And then there's the loss of information, which is of course a huge point of fear these days.
327 How is data generally handled and what information do I have to pass on? I heard in another
328 interview that the current focus is mainly on this I first collect everything I have and then I
329 see what AI can tell me about it, which is of course actually the wrong approach. So I'm not
330 yet aware of how to deal with this risk, hence the question of what experience you have
331 gained in this context?

332

333 **DK**

334 Mhm, because currently with data protection and data governance, it always depends very
335 much on who is doing it. If, for example, you have experts on board or hire an external
336 management consultancy or technical consultancy, they already do this very well, with
337 authorization concepts, data protection concepts and so on and so forth. If companies do it
338 themselves and at least take the ISO standards or have read through the guidelines, then they
339 can also do it very well. I would therefore rate the immediate significance for CE as rather
340 low. And the chance of acceleration is rather mediocre.

341

342 **Lena Sophie Thielmann**

That brings us to the topic of data itself. Nowadays, you hear a lot about how companies are still a bit hesitant, I would say, about the information they want to and can share. Which, of course, actually hinders data-based collaboration because you have to share. Can AI help in some way, perhaps through anonymization, or what is your opinion on this?

DK

So basically, as far as the exchange of data is concerned, this is no longer such a big problem because we now have a change in European regulation. So the Corporate Sustainability Reporting Directive, then the Supply Chain Due Diligence System or Directive, i.e. the Supply Chain Due Diligence Act. What else has been added? Ah, EU taxonomies, of course. So basically, these are very complex reporting and disclosure requirements that mean companies have to disclose certain data and also very disaggregated data.

Lena Sophie Thielmann

Okay, so you don't see it as such a big problem because it's a legal requirement?

DK

So from a regulatory perspective, we now have this obligation to exchange and disclose data due to certain directives. At the same time, I at least see a willingness in the industry to share data with each other, because if we share the data, we can also report better and coordinate our coordination on the circular economy better. A good example is Catena X. This is an association of different automated stakeholders who then exchange the data and enrich it with AI, making it practically a shared data platform. Therefore, the chance of acceleration is rather high and I would say the immediate significance for CE is medium.

Lena Sophie Thielmann

That means AI plays more of an anonymizing and structuring role, right?

DK

Could actually play a role wherever we do something with data. Something like data preparation, data transformation, data collection, data monitoring and controlling, etc. AI can tie in with practically any of these steps.

Lena Sophie Thielmann

Okay, great.

That's very interesting. We've already talked a bit about monitoring performance and now point 6 is about the interests of individuals or companies that they pursue in different sectors. So that goals probably go in the same, sustainable direction but are still so different that they can't be aligned, which hinders cooperation.

DK

Yes, then I would say the chance of AI acceleration is low and the significance for the circular economy is medium. Why the chance is low here is that it is less of an algorithm issue and more of a human issue. The fact that political conflicts of interest and also economic conflicts of interest or conflicts of interest within the company and between companies must also be resolved at a human level. At least at the moment, I think this is the case, which is why AI opportunities are low and the significance for CE is very high. Because different parts of the value chain have different interests and these interests often or even very often do not go in the same direction.

Lena Sophie Thielmann

Yes, exactly.

Great, then in point 7 we mean systems for collaboration, so how can performance management be guaranteed. How can this be tracked, which also addresses precisely this use case that you just mentioned? So with the collaboration platform, I'd like to hear your insights on this point again.

DK

So basically, stakeholder collaboration is a very big issue, because we have different stages of the value chain and at each stage of the value chain there are usually different stakeholders with different interests. And if we don't just have one stage where there are already lots of stakeholders, but several stages, it is of fundamental importance for the circular economy to come to a point and work out common interests or common goals. For example, if I want to make better or more circular notebooks, I have to talk to the suppliers of aluminum, cobalt and copper. So you can't do it without that and you need certain AI, monitoring and controlling solutions and also platforms or governance concepts where you can collaborate.

That's why I would say the importance for CE is very high and AI can also play a major role here.

Lena Sophie Thielmann

Then there is risk management, which means that different parties in such a collaboration naturally have a different perception of risks and perceive different risks than other companies. How do you see this point?

DK

So AI acceleration opportunity is high precisely in terms of algorithms and so on. Also in the context of data processing, monitoring and controlling and therefore high. In terms of direct significance for the circular economy, it cannot be seen as very high, but you cannot say that it is low either, so it is rather mediocre. New regulators and corporate sustainability directives are forcing you to deal with these issues. You have to report on these topics, collect KPIs and then record them quantitatively or qualitatively or partly qualitatively.

Lena Sophie Thielmann

Yes, I see, and then on the second to last point, the varying acceptance of more sustainable technologies in different countries, also mainly in developing countries, which are mainly used as landfill etc. today. There is simply little interest in participating in these activities at the moment because they are focusing on how they can develop economically today. How do you see it there?

DK

From my point of view, that would not be an ecological issue. So this acceptance will not be there and it is probably more a question of price. Because in developing countries in particular, people choose the alternative that is associated with the lowest costs. Life cycle costs are best, and ecological or sustainable products or services don't always score points here. That's why I believe acceptance and therefore rather low acceleration of AI. Because in my view, this is more of a culture and values issue, but the importance for the circular economy is very high.

Lena Sophie Thielmann

And then the last point - inflexible policies and structures in companies - how do you see it there?

DK

So AI has a very low chance of acceleration and a very high significance for the circular economy. Very low chance of acceleration, because it's about environmental standards, ISO standards, construction standards and so on. In other words, technical standards that determine the way in which we now provide certain products or services and the problem with such things is that they are super inflexible and in most cases super old. So perhaps an example now in Germany you can use a maximum of 20% aggregate in façade construction, and not for all façades, and in Switzerland it's 100% because they have long since adapted the standards through research.

In Germany, we still have the standard that applied 20/30 years ago. That's why AI doesn't play such a big role and has less chance of acceleration. But it is very important for the circular economy because it is practically the foundation of the circular transformation, i.e. the laws, standards, technical framework conditions, guidelines, etc.

Lena Sophie Thielmann

Do you think the current initiatives in politics will enable AI to tie in with this at some point in the future, or do you think it will remain inflexible given its current status?

DK

When it comes to technical standards, laws and so on, I don't think AI should be involved. Because right now, in the sense of a parliamentary democracy, laws should be decided by people. Technical standards should then be made by independent institutes.

471 **Lena Sophie Thielmann**

472 Okay, I see.

473

474 **DK**

475 At least that's my opinion.

476 I would be against AI doing anything.

477

478 **Lena Sophie Thielmann**

479 Yes, that's totally fair, then thank you very, very much, that helped me a lot and I'll pass you
480 on to the third topic, with Annelie.

481

482 **Annelie Sophie Steinbrenner**

483 Thank you very much Lena. I'm also very happy to be able to interview you today. I'm now
484 going straight into the topic of design. I've also prepared a few slides. Perhaps I'll start by
485 presenting what I had in mind. My research focuses on whether AI can improve or
486 accelerate the design of circular products. What I have found so far is that there are 8
487 different design approaches that lead to a more circular economy. Either you design for
488 longer use or you design for extended use or you design for recovery.

489 Starting here, I wanted to ask if this all makes sense to you? Or should I go into more detail
490 here?

491

492 **DK**

493 No, well, I already know that.

494

495 **Annelie Sophie Steinbrenner**

496 Okay, great. Then we can jump straight into the actual topic. Namely, how do you think AI
497 can be used in the design process and where exactly can it be used?

498

499 **DK**

500 Are you familiar with the term Building Information Management or Business Information
501 Modeling or Business Building Information Modeling?

502

503 **Annelie Sophie Steinbrenner**

504 To be honest, no.

505

506 **DK**

507 Because that might be the basic term that might be very important for this topic.

508 Can I briefly share my screen?

509

510 **Annelie Sophie Steinbrenner**

511 Yes logically. Just a moment.

512

513 **DK**

514 Because basically it's about IT capture. So basically, the idea behind Building Information
515 Modeling or Business Information Modeling or you could even say hashtag digital twin.
516 It's about looking at the holistic value chain of the product in the design process or in the
517 construction process or design process.

That means when an iPad is being designed. Or it doesn't matter whether it's an iPad or a house. It's all done in this so-called CAD program for building information management, where information is stored behind practically every component. And secondly, you can run through different scenarios in a digital environment. For example, where should I best place this wire so that it is easier to recycle later or where should I place this wire so that it is easier to dismantle later? And I think that's what Building Information Modeling is all about. It relates to both buildings and products.

And I think that's one of the most important fields of application for AI to ensure this circularity of products.

Annelie Sophie Steinbrenner

Okay got it. I haven't heard that before, so that's great. However, I now have a follow-up question. Can CAD then be seen as a way of prototyping?

DK

Exactly yes, so prototypes are created with it. So basically, prototypes can be created with it, sensitivity analyses or scenario analyses can be carried out. Practically how easy is it or how much can I disassemble from it or how much can I build from it? Or precise simulations can also be carried out. How long or how long I can use the product.

So it's a bit more complex than Building Information Management or Business Information Modeling. A little more complex, but all of this could be done with it and is in fact already being done. At least for scenario analyses. Yes, especially with buildings, this is done quite often, especially if you have the highest ambitions to build a sustainable and circular building, for example Credo-to-Credo. So if you want to identify individual components, you often do that.

Annelie Sophie Steinbrenner

Mhm, okay, got it. I'll share again now. I have found an overview here where you can see exactly which circular strategy is used in different areas, so here Long Life, Lifetime Extension and Product Recovery are 3 different goals that you can choose from. As you can see on the previous slide, Long Life is a bit like the end goal or what is favored in order to increase circularity. But the others are also possible here you can see that this can also be broken down into concept design strategies, embodiment strategies and detail strategies. And I wanted to ask you about this BIM that you just mentioned, which would probably mainly be for concept design. Would you categorize it in the same way?

DK

Yes, concept design, but also the middle part. Because there are certain mechanical and physical properties - compressive strength, tensile strength - and depending on what I use, the interactions between individual parts and individual components change. I can run through these scenarios. For example, if I have a concrete façade - it doesn't have to be made entirely of concrete - it can also be modeled in such a way that, for example, aerated concrete is used, i.e. with lots of small air bubbles. And then the same physical properties or the same physical and mechanical properties are maintained. But the use and purpose is still the same. And such scenarios can be played out with the help of AI. That's why AI can be used in the first part, but also partly in the second part.

Annelie Sophie Steinbrenner

Understood. Some research papers have already shown a few areas that can definitely be improved by AI. Maybe now, when you look at that, where do you see the biggest opportunities to actually use AI in the individual circular strategies?

DK

So concept design, that's less AI and more a software tool where you can model something.

Accessibility is less AI.

Adaptability is more of a technical topic where you have to go through scenario analysis. AI would be helpful here.

Cleanability, which is usually material selection and the composition of elements. AI would also be involved here.

Then disassembly and reassembly. That's exactly the same. So if we build everything in 3D, we can see how easy it would be to disassemble the whole thing. So yes, AI can help. The same as with BIM.

Ergonomics rather not.

Fault isolation, yes, definitely that.

Then functional packaging. That's more of a design issue. And life cycle assessment. In other words, assessment, because we have to look at which packaging alternatives have the least impact in terms of environmental impact. AI could play a major role here.

Interchagability. In my view, this is only mediocre for AI because, on the one hand, it is of course modeled somewhere in this BIM system, on the other hand, it is already a question of stakeholder communication, agreement, goals, conflicts and so on and so forth.

Yes, malfunction signaling. AI is definitely very high up there.

Simplification is definitely very high, especially when it comes to technical things.

Connection selection. Then the potential for AI would be high

Functional integration is definitely very high.

Keying. Mhm, I don't know. I think AI plays a minor role here, because it's actually a technical issue.

Choice of material. AI can do a lot there. Especially now, in this context of building information modeling or business information modeling. It can simply suggest which material alternatives are available. An algorithm that suggests you take this material instead.

Manufacturing. Definitely high.

Modularity. I think I would rather say mediocre because this is another stakeholder issue.

Something that is modular has its disadvantages and its advantages. With regard to circular economy, it can have advantages, but now with regard to certain customer wishes or certain stakeholder wishes, it can be disadvantageous.

Redundancy. No. More of a technical issue in my opinion.

Sacrificial elements. Mhm yes, of course that depends very much on the application. But basically yes.

Structural design is definitely very important.

Surface treatment selection. Also very high in any case, you can also play through this very well with BIM.

Documentation, identification, monitoring, standardization.

AI plays a rather minor role in standardization because this is a political issue.

But the other topics of documentation, identification and monitoring. AI is definitely a very good fit here, because these are actually the topics that are now the order of the day in the industry. So you can do a lot with analytics and AI.

Annelie Sophie Steinbrenner

Okay, let me ask you once again if that was the right understanding? So you would also say that this topic of prototyping is super relevant? Precisely through building information modeling and that probably counts mainly in concept design and embodiment design, right?

DK

Yes.

Annelie Sophie Steinbrenner

And this other topic with tracking, that's being mentioned more and more often precisely the designer incorporating a digital twin, for example, to see when what no longer works? Would you consider digital twins and predictive maintenance, for example, to be part of the design or business model?

DK

Well, I think they are both topics at the same time, because on the one hand, when we install something, it's a technical topic. Because if we install a sensor somewhere, a space has to be created for this sensor and so on. So it's design-driven. At the same time, this sensor carries something and then we are in the area of predictive maintenance and so on, which tends to involve business models. So I think that plays a role in both areas.

Annelie Sophie Steinbrenner

Cool. That was very, very interesting. Thank you very much, I think I'm done with my part and we're already well advanced in time. Last but not least, I'll now hand over to Lena P.

DK

I was also pleased to hear that you can send me the results when the Master's thesis is finished.

Lena Maria Pertz

Yes, we are very happy to do that. So thank you again from my side for your time and for your insights. I think we can use and reflect a lot in our thesis. If we have any further questions, we'd be happy to get back to you, but I think that's all we need to know for now? Do you still have any questions?

DK

Maybe which companies have invited you for interviews.

Lena Maria Pertz

Very different ones, so of course we have already tried to find stakeholders who have experience in both areas, which is of course very difficult. In fact, we realized that we were all the more pleased that we were able to acquire you, so to speak. Accordingly, we have a relatively large number of people who are only involved in the circular economy. Many from consulting firms, so we had Accenture, then Porsche Consulting... I think Annelie had some that were particularly specialized in product design.

DK

Mhm, okay, well yes definitely sounds cool, so good mix. But that's not three master's theses, is it?

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664 **Lena Maria Pertz**

665 Exactly, yes.

666

667 **DK**

668 Okay. I've never heard that you have to do 3 different topics.

669

670 **Lena Maria Pertz**

671 Ys. That's special. Well, thank you very much again.

672

673 **Lena Sophe Thielmann**

674 Thank you very much.

675

676 **DK**

677 All right, thank you very much and good luck with your Master's thesis, bye.

678

679 **Annelie Sophie Steinbrenner**

680 Thank you ciao.

681

682 **Lena Maria Pertz**

683 Right, see you then. Thank you very much. Bye. Thank you, thank you Ciao.

Appendix D4. TE's interview transcript

Lena Sophie Thielmann

Hello [REDACTED], thank you very much for taking the time to talk to us today. It would be nice if you could start by briefly introducing yourself.

TE

With pleasure. I was at McKinsey for more than 13 years and have now been at Camelot for about 5 years, where we do supply chain consulting. It's not necessarily focused on sustainability, but sometimes it has aspects of sustainability. The topic is of course becoming increasingly important, which is why we have many people in the team who deal with it in great detail. And I come from Düsseldorf. So, let's get started, shall we?

Lena Sophie Thielmann

Great, then I'll share my screen briefly. So the background to my topic: I looked at the topic of cooperation within the topic of circular infrastructure, i.e. how can you really close the loop in the end and how can AI support this. And I quickly came up with the topic of cooperation, precisely because this transition is a huge obstacle for companies alone and you also have to work together with your supply chain, but also with different sectors, in order to be able to take this step towards a circular economy. In my research, I came up with 27 barriers to cross-sector collaboration in the circular economy, 17 of which were said in the research to be overcome by Industry 4.0 technologies and working methods. However, Industry 4.0 is not AI per se and that's why I then looked again at which of these 17 barriers AI can really make a contribution to and build on.

TE

Mhm.

Lena Sophie Thielmann

And that's why I came up with this selection of 10 barriers and my idea now would simply be to go through the individual barriers and look at the y axis to see what their immediate significance for the circular economy really is. Perhaps you have already gained other points of experience because the barriers are currently based purely theoretically on research and then, in the second step, look at the x axis to see, what is the real opportunity that AI has for these barriers?

TE

Mhm. Okay understood.

Lena Sophie Thielmann

Exactly then I would just say we start directly with the first point, I would just briefly introduce the points and then maybe you can give your opinion.

43
44 **TE**
45 Yes.
46
47 **Lena Sophie Thielmann**
48 So the first point, the dynamics of technology, means that today, in the status quo,
49 companies and sectors in particular have different IT systems, but the development behind
50 them is also completely different. Should I go through all the barriers once? Which do you
51 prefer?
52
53 **TE**
54 Maybe you can go through them all and then I can tell you what I see as barriers.
55
56 **Lena Sophie Thielmann**
57 Yes, we can do that too. The second one is different operational and management practices.
58 This simply means that individual goals are set that restrict cooperation.
59 Point 3 is that stakeholder monitoring is different for individual companies in different
60 contexts and sectors.
61
62 **TE**
63 What does that mean? What do you mean by stakeholder monitoring?
64
65 **Lena Sophie Thielmann**
66 That different KPIs are set for companies versus public institutions, for example, because
67 cross-sector collaboration is really intended in every respect. So it's public institutions with
68 public institutions, but also with private companies with an extreme customer focus so that
69 society is included too.
70
71 **TE**
72 Thanks, Mhm.
73
74 **Lena Sophie Thielmann**
75 So it's really this whole picture of collaboration as you can envision it and it's just that
76 performance monitoring is completely different for these individual parties.
77 With point 4, we have the risk of information loss because people are not fully aware of
78 what information do I need to share? How is this handled?
79
80 **TE**
81 Mhm.
82
83 **Lena Sophie Thielmann**
84 This also extends a little into the point 5, so to speak, that there is simply a reluctance to
85 share information. People are hesitant about it.

Then we have conflicting interests of individuals, i.e. that individual parties and individuals pursue different interests and these then hinder cooperation.

Then we have a lack of standardization for the systems of cooperation. So if so many different parties are working together, how can I put real performance management behind it to track this collaboration?

Then we have approaches for risk management. The individual parties have different views of risk and perceive risk differently.

And with the nine, we have low acceptance or demand for ecological technologies. This means that developing countries in particular, which today focus on being economically viable and are also used as landfill, are currently not interested in investing heavily in sustainability and do not have the means to do so.

The last point, inflexible policies and structures, means that the structures today are too inflexible to promote cooperation.

TE

Okay, I understand and CE means circular economy, right?

Lena Sophie Thielmann

Yes exactly.

TE

Okay, and it's about: barriers that can be tackled with AI, that can be overcome with AI technologies, so to speak.

Lena Sophie Thielmann

Exactly, and that would be the first question, what do you think about the urgency of these individual barriers and then secondly, so to speak, how big an opportunity do you see for AI to somehow address them? We've already heard a lot of different things in interviews, so it's very interesting for us.

TE

So I can start by saying what I see as barriers and that is perhaps included here, but perhaps I'll say it again in my own words. Circular economy means that I have to reuse input materials that come from the end user cycle wherever possible. And I first have to find reliable suppliers who can provide sufficient quantities of such materials, for example recycled plastics granulate of certain qualities, food grade. One huge barrier is the availability of circular feedstock. We once worked with a plastics marketplace to make these streams, which are very fragmented and come from the individual mills, available in sufficient quantities. Because companies that process these things can't just provide a small box here and a small box there, they need masses of material.

A huge barrier is therefore the availability of sufficient recycled input material from reliable suppliers who then also certify it and provide it on a sustainable and continuous basis, and not once here you have something and then nothing more. Then this whole issue of

certification is really also how can you really carry out such a certification cleanly, but then also, it has to be traceable, I have to be able to assign it. This batch is now certified and these are the exact material proportions that are in it and based on waste, which is a huge challenge. And then to track the whole thing transparently for the companies, so if you now ask companies what percentage of a product is recycled content? Very few people don't even know how much that is because we have to track the entire mass balance sheet and invoice and all the flows, etc. Interestingly, we just discussed this yesterday in our Sustainable Round Table, Sustainable Value Chain, and it was about the EU's Plastic Packaging Waste Directive, which is now set to become binding and there are requirements for companies that are completely insane. In 2025, companies will now have to track and prove that they have X percent recycled content in certain categories and this content must not come from any machines, but must have gone through the full cycle from the consumer and this must be certified and proven. That's exactly what I'm saying, these are huge barriers for me. So finding suppliers in the first place, qualifying suppliers. Then making certifications trackable and making all these flows transparent, and these are all issues where AI and digital technologies are very helpful.

Lena Sophie Thielmann

Yes, you're absolutely right.

I think that's also a very important point, especially when it comes to Annelie's topic of product design. How can I use different design strategies to create this flow and where can AI tie in? That's exactly the topic she dealt with.

Perhaps if we take another quick look at the barriers, do you have any ideas about where individual barriers could perhaps be placed on the matrix?

TE

Okay, so temporal dynamics of technology is that related to information technology, i.e. information sharing?

Lena Sophie Thielmann

Yes, among other things exactly, so general IT systems are meant.

TE

Okay, so it's very important for CE.

Lena Sophie Thielmann

Mhm.

TE

And AI yes, so the question now is, when we talk about AI in detail, do you need AI for it or is it simply a digital integration that you need for it.

Group Part

170 For me, when you say AI, I think of generative AI, machine learning, neural networks, etc..
171 I'm not sure whether I need that specifically or whether I simply need system integration. So
172 I would say that there is perhaps less of an opportunity for AI.
173 For management practices. So let me interpret it this way: what is recycled content? Do we
174 actually have the right certificates and information together? AI can definitely help a lot in
175 reading and evaluating different unstructured data, so to speak, and thus making such flows
176 trackable. So I would also say that it makes a high contribution to point 2.
177 Also for monitoring, i.e. point 3. Everything that is monitoring and the structuring of data, I
178 consider both to be very important.
179 If there is a risk of information loss, I don't know whether AI can help directly.

180

181 **Lena Sophie Thielmann**

182 Do you see that as a big risk?

183

184 **TE**

185 So loss of information. Well, I think the problem is more that you don't have any
186 information, from my point of view. Not so much that it gets lost. So that you just get a
187 delivery and you simply don't have the information about how much is now recycled and is
188 it certified. So there is simply a lack of transparency.

189

190 **Lena Sophie Thielmann**

191 At this point, the connection to regulation, as you just mentioned, that's actually exactly the
192 point that's missing and then you can't actually work together with other sectors.

193

194 **TE**

195 Yes, absolutely. Point 5 poor disclosure. It's an important point, yes, but I think it's being
196 fixed a lot, now with all the regulations that are coming, no, I don't know if issue 5 can
197 really be solved with IT. So I can see that it's definitely important, yes, but it's not an AI
198 issue.

199 The interests of individuals are not aligned. I would see it similarly, so it's definitely an
200 issue, but it's not an AI issue.

201

202 **Lena Sophie Thielmann**

203 Mhm.

204

205 **TE**

206 Lack of standardization of systems: Yes, I would also say that this is important in terms of
207 resources, but more to the right, so I think everything that can be read from unstructured,
208 non-harmonized systems, information, data can be made comparable. AI can help with that.

209

210 **Lena Sophie Thielmann**

211 Yes.

212

213 **TE**
214 Point 8: Risk management. I can't say that. For me, it doesn't have that much to do with AI.
215
216 **Lena Sophie Thielmann**
217 Mhm.
218
219 **TE**
220 That's a bit abstract for me, I can't really put it into perspective.
221 What exactly do you mean by low demand for ecological technologies? Is that an issue?
222
223 **Lena Sophie Thielmann**
224 I've read that developing countries are rushing into the landfill issue, simply because they
225 are building a network with more economically developed countries and simply don't have
226 the money to make major changes right now, so they are using more sustainable
227 technologies in order to be part of a collaboration in the circular economy.
228
229 **TE**
230 Okay, so then you could even say that's high, but I don't see the AI impact directly.
231
232 **Lena Sophie Thielmann**
233 Mhm probably more of a communication issue then, right?
234
235 **TE**
236 Communication topic and also regulations, i.e. laws, regulations and also other incentives
237 such as taxes etc.
238
239 **Lena Sophie Thielmann**
240 Yes.
241
242 **TE**
243 Inflexible policy. Yes, that's definitely an issue, so I don't know if you're always looking at it
244 globally, but as I said, a lot is happening in the EU. Many people in Germany would almost
245 say it's radical, yes, it's tough, what's being implemented and all that. But that's a good thing.
246
247 **Lena Sophie Thielmann**
248 That means that the problem for the circular economy is no longer so great because so much
249 is already happening.
250
251 **TE**
252 Yes yes, but also not an AI topic exactly.
253
254 **Lena Sophie Thielmann**
255 Okay.

256

257 **TE**

258 So I see AI very strongly in the harmonization, making unstructured data readable, and
259 there's a lot of that in this topic.

260

261 **Lena Sophie Thielmann**

262 Yes, that's definitely true.

263

264 **TE**

265 There are no standard interfaces yet, no standards for how you have to report this content,
266 it's not there yet.

267

268 **Lena Sophie Thielmann**

269 This means that AI can be used for these different systems that need to be harmonized.
270 But also the different goals of the individual parties and this is probably the main point of
271 contact for AI to take on this structuring role.

272

273 **TE**

274 Exactly, it's important to say, for example, in point 1 AI is not the same as IT, but then you
275 make an interface and don't have to use the highly sophisticated things like AI here. That
276 would also be inappropriate.

277

278 **Lena Sophie Thielmann**

279 Yes, that's right, okay, great, then we're already through with my part. Thank you very much
280 and I'll hand over to the other Lena.

281

282 **TE**

283 With pleasure.

284

285 **Lena Maria Pertz**

286 Thank you very much Lena and thank you again for taking the time to talk to us, so I'll talk
287 about the circular economy in relation to business models and then I'll also share my slide
288 very briefly so that we can take a look at it a little bit and see what's going on, and I've read
289 a lot in my research that there are already 5 different business models. In the area that we see
290 here on the left and that are shown a bit on the right, such as these business models that
291 close the cycle again, so to speak, and are important processes, such as recycling or
292 manufacturing - which are all activities that close the cycle again, but then there are also
293 processes that slow down the cycle of a product, such as repair or upgrade or the whole topic
294 of the sharing economy. And I took a closer look at these processes and then tried to write
295 them down here. I tried to find the most important processes. Perhaps you would like to take
296 a quick look at whether all the processes are covered from your side or whether something is
297 still missing in the first step.

298

TE

So the topic of sharing, do you have it in there somewhere? Yes, leasing subscription, but also that you now say consumers use, for example, recyclable products from the outset, let's say, and so in principle avoid consuming resources, do you know where that is included?

Lena Maria Pertz

Yes, I think that's actually the starting point of a circular economy in general, so that's what my topic is about, so I assume that all the products that are used in these processes have been designed for circularity, so to speak, and I deliberately don't look at the topic because it's one of Annelie's topics. That's why nothing is included here in the table with regard to product designs, so I actually look at processes in the value chain afterwards, i.e. really in use or also in the end of life.

TE

Yes, then it makes sense how you have the 6 elements there, something like longevity issues.

Lena Maria Pertz

Okay, great, yes, perfect, that sounds good, exactly, and I've been thinking a bit about how to introduce the topic. How can AI really help to optimize these topics? And then in the next slide I wrote down a bit about which processes within these business model elements can be improved and accelerated by AI, maybe we can just go through the topics and you can give us your opinion, your assessment. Exactly the first topic of end-of-life take-back systems would then be, so to speak, when the products go back, so to speak, the product is then also included in small processes. In these take-back systems, the product first has to be picked up again by the customer somehow. It has to be transported. And so that this can take place, the product is taken apart, ideally refurbished or disposed, and that's where I found out that route optimization, so to speak, can take place in relation to AI using various algorithms, including match and clustering. Especially in the first 2 processes, collecting and transportation, the routes of how the products are picked up and transported, so to speak. This can be optimized and emissions can be saved accordingly. Which is also very sustainable and, in the best case, the product returns to the producer in the most efficient way.

TE

So I think the two things make a lot of sense to me. Applying visual recognition for waste sorting guarantees purity of waste being one of the most pressing AI applications in take-back systems as it ultimately maximizes the value of recycled materials.

Lena Maria Pertz

I definitely see the point that you can also do this with other digitization or historical data products. There doesn't necessarily have to be more algorithms elsewhere, but I think it's important with ice cream. That it is also partly real time, so that you can draw parameters.

How is the traffic right now? And then, it's okay to look at the current basis and not just historical data so that the route can be optimized.

TE

I'm not sure about this kind of transportation, you know, if you have a huge truck with a lot of plastic shredders, do these types of products with such a low value even need this level of route optimization or shouldn't you rather try to integrate AI in other places?

Lena Maria Pertz

Ok yes, fair point. If you then use AI, it's also a very complex topic that you might not look at in route optimization first, but in sorting.

TE

Yes, where, I've been thinking about it all the time, but I don't have any idea whether there's anything in terms of customers, i.e. closer to the consumer, yes, where, where you have such facilities, consumers, feedback, usage behavior and in any apps.

Lena Maria Pertz

That is actually covered in point 6, I have that as a single point customer intelligence, because I also read out a bit that in the circular economy, customer contact, co-creation is very, very important, namely that, as you said, feedback can be used correctly by the customer and that's exactly what I have now. Chatbots are virtual systems on the one hand, but the sentiment analysts have also found analysis algorithms that allow feedback to arrive directly at the right place, so to speak and not somehow collected somewhere and then the feedback disappears, so to speak, which is immediately clear ok good, the feedback is classified in such and such a way and sent here and there at the value chain point. Exactly that would be point 6 then maybe we continue with point 2, any kind of service that is offered during the product life cycle, so to speak, while the customer is using the product, it is particularly important in the circular economy that certain services are offered in relation to my maintenance and repair so that the life of the product is kept as long as possible, so to speak, and I have found a lot about predictive maintenance I don't know if you might have a point of view on that.

TE

The industrial company doesn't use it, there are definitely trials. There is something to be sensed about machines, how machines behave, which is also unstructured data again and because patterns may support, so when it comes to repair flows, it's also about repair flows. Maybe again, how do I even find, so to speak, I don't know if there aren't also platform topics, where maybe that's also under Customer Intelligence again? So I think an AI use case is bringing together the intelligence of people who have service and who have material, there are also many business models that are so, for example, Atomler they make plastic marketplaces and stories like that, so I would simply take up this whole topic of marketplaces and so on as a business model again.

385

386 **Lena Maria Pertz**

387 Okay, yes, can you perhaps tell us a little bit more about what exactly models are like
388 Atomler?

389

390 **TE**

391 All of them are at least start-ups, so I don't know how much money they really earn, but I
392 can say that, it's simple, that's what it does for plastic, they just bring recycled plastic
393 together with people who need recycled plastic.

394

395 **Lena Maria Pertz**

396 Okay, that's interesting of course, yes, maybe it's generally another point that I've just
397 noticed myself that's missing, that's the seventh point, that you theoretically look again at
398 recycling services or processes, like those of AI. That might be a good place to start. Have
399 you done that again?

400

401 **TE**

402 Well, I think many of these things have, you have complex ones.
403 So the normal process is, of course, you go to the Apple Store and buy the iphone, but when
404 you have all these backwards processes, it all becomes much more complex, you always
405 have a lot of people who have something and how does it find its way back? So all this
406 matching is the important thing, from my point of view.

407

408 **Lena Maria Pertz**

409 Yes, yes, it was perhaps also important to say that all the components here can of course also
410 be combined, so as you said, the platform solution platforms can definitely be combined
411 with a topic such as 2 service offerings and they are not mutually exclusive, which is also
412 important to mention again. Exactly then with the third point also again reference to
413 customers. Whether it's B to B or B to C, that you simply offer certain types of training and
414 consulting and I was thinking that you could simply use predictive analytics, i.e. you look at
415 historical data and can then, based on the historical data or simply how, for example, the
416 condition of a piece of equipment is at the moment and can the customer somehow need
417 training or a consultant because it's not running at the moment? How production should run,
418 and then you can proactively send recommendations and set appointments so that you can
419 optimize the process.

420

421 **TE**

422 Exactly for me a lot of things look like this, I would also put it under training and nudging
423 "do it now" or don't take your iphone with you in the rain when it gets wet, dry the thing
424 now I should be so direct with you, so we also have that direct service.

425

426 **Lena Maria Pertz**

Very good point. Yes, I will definitely include that. Exactly then the fourth point is leasing and subscription and that is also very common in the B to B area, that devices are often leased, that you can then simply send automatically, you already know that theoretically at the beginning and then the subscription is over or this contract expires and then simply notification is sent with, for example, new options for an extended extended leasing option, that you then simply look at the economic aspect and try to generate a bit more revenue and then suggest this to the customer based on such notifications and?

TE

So yes, I have the other, so what makes sense to me. This, if it's an end-of-rental notification, not necessarily AI, but if what it says underneath is combined with analyzed usage behavior and derives services from it or something, then it's back into AI.

Lena Maria Pertz

Yes, because what I have also noticed is that people often only look at all these AI use cases to see how value can be captured/delivered. I've now tried to find out how it can be seen economically, which of course is not necessarily the focus in the circular economy. But it would be nice, I would also like to see a use case on how to support the AI approach in relation to the revenue model, for example. Sharing Platforms, knowing that a certain product or the resources is needed by one person which another one can offer, and because of this complexity, AI can of course provide great support, cluster all the different parameters and bring the certain actors together in an almost automated way, if the certain data is of course there and also structured and prepared in such a way that it can be used precisely.

TE

Mhm So for me, that's also an aspect of usage behavior, there is also complex data on who is using what, so to speak, to improve the services offered by such sharing platforms.

So according to the motto I don't know in principle, he needs the car and then it's as close to me as possible, if I now have a car sharing example, because these things are always worse in terms of service level than your own product, which you own and the more you need, that's a big area of application for AI from my point of view. Sharing offering has just as high a service level as your own, so it can't be exactly as high, but it comes as close as possible to your own, if I own the sharing car exactly as close as I'm likely to need it as my own, so to speak, and of course you can control that very strongly with AI.

Lena Maria Pertz

That's right, okay, I'll write it down perfectly and we've already talked about the last point. Customer intelligence, can you think of anything else that AI could support, regardless of the processes? In terms of process optimization in the value chain?

TE

No, I think all essential parts were covered, we've gone through everything now, I think it makes a lot of sense.

Lena Maria Pertz

Okay great that sounds good, then thank you very, very much for your validation of some topics, but also for the new input. And then I would say it's time for Annelie.

Annelie Sophie Steinbrenner

Exactly, thank you very much Lena. I'd say I'll jump straight into my slides and just go through them with you. So, first of all, my research focus. We're all looking at the circular economy and artificial intelligence. For me, the third topic is product design and specifically the question: can AI improve or accelerate the design of circular products?

And for this, I have now looked at a specific framework from literature that specializes in design to maintain the circularity of products. The idea is that there are 3 major goals.

The first goal is long use. The second is extended use and then the third is recovery and there are different design strategies that contribute to each of these goals.

My question now would be, how can AI actually help to realize the design strategies and goals?

TE

Mhm okay, so okay. Let's start on the left with long use. So emotional durability is how do you design a product in terms of appearance, in terms of the brand, right?

Annelie Sophie Steinbrenner

Right exactly so an example here would be Saddlebag. These are old or, let's say, vintage leather bags that are inherited because they don't break. Of course, they have both a physical durability and an emotional durability because they are inherited. And a few scratches in the leather don't mean that they have to be replaced, but perhaps even tickle an additional emotional connection to the person based on memories.

TE

Good, here I can imagine that you are using consumer behavior analysis. So that's more of an analysis topic like how AI can help. Maybe AI can analyze patterns in consumer behavior, or what drives long-term loyalty to the product?

I don't think that's the easiest thing to do, because I don't know to what extent it can be modeled. But I think AI could at least help to understand or analyze something like that.

I can definitely imagine that AI could help with the second one. You're now in the area of simulation or something from my point of view, right? That you say you somehow have a kind of digital twin of a product and are now simulating - I don't know exactly what role AI would play there, but it would certainly play a role - you are now somehow simulating a hundred years of use in different scenarios by different types of users and so on.

510 I don't know to what extent AI can also do problem solving in this way. Along the lines of,
511 what are the drivers now? What are route causes for wear and tear or failure? AI can
512 certainly provide support here.

513 I imagine it along the lines of - not like a physical test, where someone always presses
514 something on the chair, at Ikea - but everything is played through in 10,000 cases with
515 different constellations, calculated and insights are then determined from this. What are the
516 most important design factors for durability, etc.? AI can certainly do a lot here.

517

518 **Annelie Sophie Steinbrenner**

519 Yes, I understand that.

520

521 **TE**

522 And something similar, I would have said now, you can also do in 3, Maintainability. So
523 that's all a topic for me: playing through product usage, repair cases, etc. So I think 2, 3 and
524 4 are very similar.

525 And upgrading. I don't know how Ai can help with that. For me, that's more a question of
526 product strategy, isn't it? I'm having a bit of a hard time with that. I don't know. I don't know
527 much about that either, to be honest.

528

529 **Annelie Sophie Steinbrenner**

530 No problem at all.

531

532 **TE**

533 Go on now. It's all about recovery. So I imagine... What's it called here, urban mining. That
534 you build a house and it's built in such a way that you can take it apart again afterwards.

535

536 **Annelie Sophie Steinbrenner**

537 Yes yes, that's exactly what this topic is about, disassembly is very big in these recovery
538 processes and that you try to build it into the design process. How can different components
539 be disassembled in order to get the components and individual parts back as easily as
540 possible?

541

542 **TE**

543 I think that's a bit similar to 2, physical durability. It's a complex topic. What outputs do you
544 get out of it afterwards? So assuming any steel grids or frames or whatever? How do they
545 have to be configured, designed, so that there is a market for them afterwards or so that they
546 can be reused in a meaningful way? And what is the best way to install them so that you can
547 get them out again with reasonable effort?

548 I'm guessing that you can simulate something like this using digital twin.

549 But I'm a bit conjectural about that. I'm generally not that into design topics.

550

551 **Annelie Sophie Steinbrenner**

552 Exactly. Just to summarize again. Do you actually see the greatest opportunity in simulation,
553 either through the digital twin due to real-time data collection, or in relation to prototypes?
554 That you play through different simulations before the product is manufactured?

555
556 **TE**
557 Exactly.

558
559 **Annelie Sophie Steinbrenner**
560 Well, I've already written down AI design approaches from other interviews and tried to
561 segment them into different phases.
562 The first thing that was mentioned more frequently is the pure design or pure layout of
563 products in the ideation or conceptualization phase. Trying to generate inspiration based on
564 past data.

565
566 **TE**
567 Yes, that makes sense to me. There is already software and AI that can be used there.

568
569 **Annelie Sophie Steinbrenner**
570 And then on the second topic, I've read a lot about material extraction and I'd like to ask you
571 about that again. You mentioned earlier with Lena Thielmann that material selection or
572 input materials should already be checked in order to ensure circularity in the end.
573 I would like to ask you again how exactly AI can help here or what your basic idea was?

574
575 **TE**
576 Materials all have to have a composition, especially when it comes to Co2 or recycling share
577 and precise dimensions. The properties are usually not available in a standardized form.
578 These are then some kind of data sheets or specifications. This is unstructured data, which
579 can be recognized very well with AI, let's say very strongly, automated and then made
580 comparable. Which would otherwise be a huge manual effort.

581
582 **Annelie Sophie Steinbrenner**
583 Yes, understood. Okay, so you would definitely agree that material selection and
584 optimization are an opportunity for AI?

585
586 **TE**
587 Absolutely, you could now also somehow screen available specifications that are somehow
588 available on the web for materials or a database about it. And see where we can find suitable
589 materials that meet certain values. So it doesn't necessarily have to be tracking, it can simply
590 be research.

591
592 **Annelie Sophie Steinbrenner**

593 Yes understood, ok. Then perhaps to point 4: improved and faster identification of errors. I
594 think that's relevant for prototypes. As you said, with the simulations, and then through real
595 data while the product is being used, in the case of Digital Twin, right?

596

597 **TE**

598 Exactly you can of course also measure values on a test and analyze them again with AI and
599 so of course understand much better why something leads to failure and so on, ne? It's very
600 similar to attaching sensors to the machine and having them analyzed by AI in
601 manufacturing.

602

603 **Annelie Sophie Steinbrenner**

604 Mhm, yes. Now traceability. You mentioned that as a buzzword earlier. How can AI help
605 here?

606

607 **TE**

608 Yes, exactly. What we just said. Digital Twins can be used in maintenance as well as in fault
609 prediction based on historical data and real-time data.

610

611 **Annelie Sophie Steinbrenner**

612 And then I also wanted to touch on AI-based intelligence for traceability. Is that really
613 something you should think about at the design stage?

614

615 **TE**

616 So is that in the physical product or is that more in the information that's supplied with the
617 product, that traceability?

618

619 **Annelie Sophie Steinbrenner**

620 I would argue it's more in the information, so the latter.

621

622 **TE**

623 There again, you have some standards sheets, specifications that are unstructured and that
624 you can compare or read out better via AI. Directly on the product, I don't know.

625

626 **Annelie Sophie Steinbrenner**

627 Okay, all right. Now product design, based on end user feedback.

628

629 **TE**

630 That's also a good application for AI, just unstructured feedback from consumers, so to
631 speak, maybe not in standard questionnaires either, but just so sentiment-wise. What do
632 consumers say? Of course, you can also evaluate this again with AI or perhaps even use it to
633 automatically create designs at some point. Designs that are then personalized and best
634 suited to these people

635

636 **Annelie Sophie Steinbrenner**

637 Okay. In addition to the design measures, can you think of any other use cases where AI
638 could help?

639

640 **TE**

641 No, nothing that comes to mind immediately.

642

643 **Annelie Sophie Steinbrenner**

644 Okay, all right. Great. Then that's it from my side and then I would like to thank you for
645 your time. I think we can definitely take away many, many valuable insights from this
646 conversation and incorporate them into our master's thesis.

647 Now I would like to hand over to Lena Thielmann again and wish you a good rest of your
648 day.

649

650 **TE**

651 All right, thank you.

652

653 **Lena Sophie Thielmann**

654 Yes, from my side as well. Thank you very much. Really. You saved us a bit with that and
655 definitely helped a lot.

656 I don't know what your impression of our research might be, i.e. whether you think we're
657 actually quite well positioned in terms of the circular economy? Or have you missed
658 something or is there something that we may have completely overlooked?

659

660 **TE**

661 Yes, I think you have good approaches and I think you've also seen that because sometimes
662 everything goes a bit haywire with AI and I think many people use AI and don't really know
663 what it actually is.

664 And you could tell that you thought about what AI can do in particular compared to perhaps
665 normal modeling optimization.

666

667 **Lena Sophie Thielmann**

668 Yes. People talk a lot about AI, read a lot more about it, and you can get lost super quickly
669 and that was also the challenge for us, so to speak. To break the topic down to the essentials.

670 That's why we're pleased that it seems to have worked.

671 We're very excited to see how the evaluation turns out in the end, but thank you very much
672 and we'll definitely see you soon.

673

674 **TE**

675 All right, great, then take care.

676

677 **Lena Sophie Thielmann**

678 Thank you ciao.

Group Part

679

680 **Lena Maria Pertz**

681 Thank you very much, yes, bye, thank you very much, bye ciao.

682

683 **TE**

684 Well then, good luck with your work. Bye bye.

Appendix D5. PdH's interview transcript

Lena Sophie Thielmann

Thank you very much for taking the time to talk to us today. Could you maybe start by introducing yourself?

PdH

Yes of course. My name is [REDACTED] and I have a wide variety of knowledge in the field of AI. Currently I am working as a Vice President for Artificial Intelligence at Gartner.

Lena Sophie Thielmann

Thank you very much for the introduction. As we have a little time constraint I would start right away with my part about circular infrastructure and collaborations. So today we are talking about barriers for a circular economy collaboration. And the first point basically means that you have different status quos in the IT systems of the collaboration partners. But when engaging in collaboration you need to find a way to work together despite that.

PdH

Regarding the temporal dynamics of technology and the different versions of the technology even. There is often a big hurdle in this domain regarding the reconsolidation/ integration of data between different systems. You know, semantic differences, synthetic syntax differences between data. AI can play a role to I think there is, you know what we call data augmentation, where AI helps to relieve some of the challenges and ease some of the challenges there, I think there is a medium to high opportunity. I would put it a little bit more to the left. Is it important for CE? Yes, I think it's very important. So I think, you need to automate this. Yeah, I would even put it a little bit more to the right, if I may.

Lena Sophie Thielmann

Yeah, of course.

PdH

Yeah, somewhere there.

Yes, yes, yes, that's it.

And #2.

Lena Sophie Thielmann

Yes, distinct management practices. So the different partners or parties of a collaboration do have different practices and management practices and planning practices and you need to align those. For example, in the stability and circularity approaches that you kind of come on one level and have a collaboration there.

PdH

Umm yeah, I find that less clear how AI could play a role. I mean, there may be a role to

44 some harmonization there, but I think it's. Yeah, exactly. And is it important to circular
45 economy? Yes, but to a lesser extent. So yeah, I agree with that positioning that did.
46 OK, #3 monitoring performance.
47

48 **Lena Sophie Thielmann**

49 So the stakeholders performance monitoring for the different collaboration partners is
50 different in the different contexts and sectors. For example, because cross sector
51 collaboration includes not only business to business collaboration but also business to
52 public, also with business to society, for example. So there is a lot of different performance
53 tracking options that you need to include.
54

55 **PdH**

56 Yeah. I think AI can play a role to basically contextualize performance information to
57 different audiences or different contexts. So yes, it could be. I think AI could be a little bit
58 more to the right, somewhere around there. Is it very important? Umm, no, I think it could
59 be a bit lower I feel, but yeah, it's a bit arbitrary.
60

61 **Lena Sophie Thielmann**

62 Because it is kind of an automatized process or why?
63

64 **PdH**

65 Why lower?
66

67 **Lena Sophie Thielmann**

68 Yes.
69

70 **PdH**

71 Well, because I think that, uh, circular economy initiatives. Of course, there are multiple
72 contexts, but uh, I mean a lot of practical examples around CE are also bipartisan. So two
73 companies working together, so then it's less of an issue I feel. So yeah, that's why I put it a
74 little bit lower. That was my thinking behind that.
75

76 **Lena Sophie Thielmann**

77 OK. Thank you. Then we have the risk of information loss, because today it's a bit unclear
78 on what kind of information needs to be shared and how is it stored.
79

80 **PdH**

81 Yeah, yeah, yeah. This is where I think especially generative AI can play a role to, assuming
82 it has access to the data, that you know people do not always know in advance which
83 information is relevant to other potential consumers of their waste products. So I think that
84 is also very hard to foresee. So I think AI can really, you know, be a sort of a broker where
85 it's looking proactively for information that is relevant for another company. And I think
86 actually it could be even higher if you ask me. Yeah, they're about.

87

88 **Lena Sophie Thielmann**

89 And then we have the reluctance to share information because it's kind of like a new thing
90 that employees and stakeholders have to engage in. How do you see that barrier?

91

92 **PdH**

93 I see that most as a cultural barrier, to be honest. So I'm not so sure how AI can really help.
94 Maybe a little bit in, but that is more of a cultural issue. So I would put that more to the left
95 and but it is important. So let's say medium importance a bit lower. I would say a little bit
96 more to the left.

97

98 **Lena Sophie Thielmann**

99 Umm. Then #6 we have the different interests that are present in the different sectors. So for
100 example, in the business context and the public context or in the societal context.

101

102 **PdH**

103 There I think AI could play sort of medium role in the sense that it can help to maybe make
104 people understand how their interests relate to other interests. Perhaps. Maybe a little bit
105 more to the left, even to be honest with you. And I think the vertical axis is OK, yeah.

106

107 **Lena Sophie Thielmann**

108 Great. Then we have the absence of a system for the performance management of the
109 collaboration itself, because prior we talked about the different performance trackings in the
110 different for example, companies and public institutions. But now it's the lack of a system
111 that actually tracks the collaboration effect.

112

113 **PdH**

114 I think to me it relates to #1 a little bit. But number one is more general, I would say. So I
115 would put it somewhere in the same area, yeah.

116

117 **Lena Sophie Thielmann**

118 And then we have the risk management approaches because the different sectors and parties
119 and perceive risk in different ways and also have different aspects that they consider as a
120 risk. How do you find that barrier?

121

122 **PdH**

123 I feel there is also a sort of cultural or non-technical dimension here, so I would would not
124 rely too much on AI to resolve that barrier. Maybe.

125

126 **Lena Sophie Thielmann**

127 And for circular economy itself, the risk management approaches. How do you see that
128 combination?

129
130 **PdH**
131 So a #8 you mean?
132
133 **Lena Sophie Thielmann**
134 Yeah.
135
136 **PdH**
137 I find it hard to can you give me an example of a risk that you that you have in mind here?
138
139 **Lena Sophie Thielmann**
140 For example with the new regulations coming into place, you have to have like a certain
141 know amount of recycled materials in your product. But you don't have the suppliers today,
142 so that's actually a risk that you have to approach when engaging in circularity activities and
143 the companies do perceive those risks differently because if you have a tangible product, you
144 perceive it differently than a service company. But that's the role of the barrier I had in mind
145 when it comes to circular economy.
146
147 **PdH**
148 Yeah. Reminds me of a risk that sometimes suppliers of waste materials for them it's not so
149 much, you know, an issue if it's a bit late. But for manufacturers that are using their base
150 materials as raw material for their own manufacturing they perceive it as a much more
151 critical that the availability of such materials takes place in time. So yeah, I think it's pretty
152 important. I would move it up to.
153
154 **Lena Sophie Thielmann**
155 OK, great. And then we have the 9th point, which is the lack of demand and acceptance for
156 environmentally superior technologies. For example, in developing countries, because today
157 there are mainly used as landfill and focus on that as an economic activity for them and are
158 not really interested in investing in like really environmentally superior technologies, what
159 do you think about that?
160
161 **PdH**
162 Yeah, I think it is important on the vertical axis. Uh, so pretty high, but not very high. I
163 would put it slightly below 8 or perhaps move eight a little bit higher, but anyway. And also
164 horizontally I think to me that is again, there are multiple factors that drive that demand, one
165 of them is perhaps a lack of information or knowledge about such technologies, there AI
166 could help, but I think more important drivers are, you know, what is sort of the incentives
167 for companies to use such technology. I think that's a far more important factor than the
168 availability of information. Ohh yeah, I wouldn't put it too far to the right.
169
170 **Lena Sophie Thielmann**

171 And the last point, inflexible policy and structures, how do you see that in the environment
172 of circular economy and AI?

173

174 **PdH**

175 What again is C-SC and CSCM?

176

177 **Lena Sophie Thielmann**

178 Cross sector collaboration and circular supply chain management.

179

180 **PdH**

181 OK. Yeah.

182 Yeah, I think this is actually where AI can play an important role.. That barrier could be
183 lowered by having AI offering a platform across sectors where you know there is a more
184 instead of adhoc 1-1 collaborations. Ideally, there would be sort of a structure across sectors
185 where you can find opportunities for collaboration in a more systemic manner.
186 Because without AI, the amount of information would quickly be overwhelming for
187 participants in such a platform. AI could help to personalize and and adapt the available
188 information and also suggests certain possible opportunities.

189

190 **Lena Sophie Thielmann**

191 Yeah, of course.

192 Very, very, valuable points. And then thank you so much.

193 Then I'm already done with my questions and I would hand over to Lena.

194

195 **PdH**

196 Yeah.

197

198 **Lena Maria Pertz**

199 Thank you, Lena. I will be the next Lena and I'll talk about the business model; the circular
200 business model and I quickly share my slides for that. So we can also have a look on what
201 I've researched so far. During my research I came across 5 main business models of circular
202 economy which you can basically see here in that value chain on the right. And I was
203 looking at the different processes that make value chain circular. So, for example, the reorg,
204 upcycling the remanufacturing, the reselling of already existing products or the service of
205 repairing and maintenance. And on the next slide, actually defined six of them, which you
206 can see on the left hand side of the slide. And I tried to already find some AI use cases for
207 these different types of processes of a circular business model and maybe we can go through
208 these different processes and through my ideas of AI use cases
209 And maybe you can validate them or give other opinions or ideas, or your perspective on
210 those. That's perfect, so maybe we start with the first, which would be the end of life. Take
211 back systems. So basically the process of getting a product of its end of use and collected,
212 transported back to the to the vendor and sort it like sort the different materials resources,

disassemble it, refurbish it and then in the end disposal like have the disposal of the non recyclable materials and.

PdH

About your last question I think that one use case that I was thinking of there is the use of AI to umm to take the let's say good demolition of the OR the refurbishment or the taking apart of a product that is end of life into account in the design. Uh, so you can design a product in such a way that you that it's when it's end of life relatively easier to take it apart and have more unusual parts as a result of that. And I think there's an interesting case where I could play role to to to take that also into account in the design of your product, although it's still early days, I think there's still some, there's yeah, payroll there.

Lena Maria Pertz

Umm yeah, I think so too. And I think this is definitely discussed later with Annelie because she's having the product design part. So that's why I'm looking only at the end of life. So when the product was already designed, hopefully in a way that it can be. Take back in the system basically. So this is already a good input, but maybe we can talk about the ideas I had in turn in terms of the AI use use cases for this process, which would be the route optimization. So basically the first two processes, so collecting and transporting the actual product. So I could maybe have matching or clustering algorithms to find efficient routes, get the A product as quickly and as environmental friendly as possible back to the vendor.

PdH

You mean for? For demolition?

Lena Maria Pertz

Yeah, yeah.

PdH

The only new ones I would that makes sense, but you only knew once. Would bring in. Is that who is to say that it is also the vendor that is going to take a part of the products? Uh, because they may also be other facilities to do the to do the demolition or whatever you call it. And the other Moodle for medication that may be useful there AI role is to. Just to predict where certain waste materials will be needed by other manufacturers. So that could be effective to take into account. So rather than, you know, bringing all, I don't know, refrigerators to the same facility, maybe you can better bring them to the facility that is already closer to the to the main uh to to the places where demand for for the outcoming uh waste is is greatest if that makes sense.

Lena Maria Pertz

And then getting to the next process, which would be the service offerings that are mainly for product service systems, so that you offer basically to the customer maintenance, repairs

256 and upgrades in a very regular time so that you keep the product as long as possible in one
257 life cycle. And for this one I have a pretty obvious AI use case, which would be the
258 predictive maintenance. So that you basically anticipate when a plant or any other kind of
259 equipment could have a potential failure in the next next time or schedule even maintenance
260 services before the actual product breaks down. And what is your opinion on that which you
261 agree? Or do you have any other use cases?

262
263 **PdH**
264 No, I I would agree. But I would even take it further. There are some early experiments
265 where you have equipment that own also apply that internally and they can change
266 sometimes the way they are operated.

267
268 **Lena Maria Pertz**
269 OK, so basically automated a little bit.

270
271 **PdH**
272 Yes, exactly.
273 And then adding to that another use case related to that is to have an AI chat bots or
274 something similar that assists the the the operator of the equipment in in in actually doing
275 the maintenance the you know that could be the replacement of a part or it could be
276 something else to to to do maintenance. But yeah, that could be another use case there.

277
278 **Lena Maria Pertz**
279 I actually found the use case of a chat bot in another process which I called customer
280 intelligence, because I read that the Co creation of the customer and the vendor if it's B2B or
281 B2C is very important in circular economies. So therefore also thought chatbots or any kind
282 of virtual assistant could be helpful in this way as well, because the feedback of the
283 customer could be directly get to the dedicated business function where the feedback should
284 be basically implemented. What is your opinion here?

285
286 **PdH**
287 Yeah, yeah, yeah. No, that makes sense. So having a more direct connection in essence
288 between the users and the designers of of a system, if that's what you're saying, yeah.

289
290 **Lena Maria Pertz**
291 Yes, correct. Yeah, that's definitely what I was saying.
292 And then regarding the next process, which I'll thought about resale and one very famous or
293 popular example was leasing that you basically rent product for a short time and then you
294 give back the product. And in this case I thought about automated end of rental notifications.
295 So basically all these reoccurring administrative review data driven processes that
296 Commonwealth such a leasing contract could be basically automated also with AI.
297 And on top of that, you could also try to enhance your customer retention strategy by that.

298 So you're basically use this historical and time series data of your customer's behavior and
299 try to actually implement some personalized promotions or loyalty plans or like to
300 encourage them that they actually stay with the leasing contract.

301

302 **PdH**

303 Umm yeah, that makes sense. I I think I would agree with those use cases.

304 Perhaps at another one, and that is the for the company that leases the equipment or products
305 to enhance their demand forecasting. All all also at local levels, so they can optimize the the
306 distribution of the of the of the equipment they want to lease to consumers or other actors.

307 So yeah, that would be another use case, OK.

308

309 **Lena Maria Pertz**

310 And then the last one would be the sharing platforms, which are I guess also very famous
311 way of having a circular business model, right? Yeah, in today's world, basically and for this
312 one, I thought and potential AI use case would be that you can also use again these matching
313 and clustering algorithms to basically automate the return and swap process of products. So
314 basically you have that marketplace and you basically connect the person with the product
315 with one customer or user that actually has the need of that program product and that you
316 can find automated optimal matches based on matching parameters and stuff.

317

318 **PdH**

319 So basically facilitating the the matching that that that you want on the sharing platform.

320

321 **Lena Maria Pertz**

322 Umm, correct. Yeah.

323

324 **PdH**

325 Yeah, yeah, that makes it that.

326 It makes a lot of sense, and with AI you can improve the uh, the personalization.

327 Uh, and, you know, increase the quality of the matching.

328 Yeah, that's all that.

329

330 **Lena Maria Pertz**

331 Perfect. That's amazing. I think we also ready for my part and we are in time I guess.

332 Thank you so much.

333

334 **PdH**

335 You're welcome. But I also had one other English case that I wanted to mention that which
336 is maybe. I'm not sure it's relevant for your piece of the work, but.

337 And it's it's still also experimental, but it really it relates to modularization or
338 componentization. I think it's the word of products and you know The thing is that there is
339 also a trade off if you if you make your components bigger and more integrated, they're
340 easier to swap and easier to a major because it's, you know, you just have an integrated

341 component. You can take it out and replace it with another one, but it's actually bad for in in
342 general for circular economy because you know the bigger the component, the more
343 different materials will be in it and in general and you know, the harder it will be to take it
344 apart, because it's often very much integrated. Also physically so there is an optimum that
345 we found in sort of the the way how you. How you design your products using components
346 that, umm, are on the one hand big enough to get out to provide the ease that I described
347 building or doing maintenance with the product.
348 Anyway, because the long short short is optimization of of module size or component size, I
349 think it's another use case where I think AI could be playing a role.

350

351 **Lena Maria Pertz**

352 OK, I think this is actually a bit more of the topic of Annelie, which is the perfect transition
353 basically. Ohh excellent. So she already has the use case.

354 But yeah, thank you so much for the for the last 15 minutes, it was very helpful.

355 Have a nice day.

356

357 **PdH**

358 You too.

359 Thank you. Bye.

360

361 **Lena Maria Pertz**

362 Thanks.

363 Bye, bye.

364

365 **Annelie Sophie Steinbrenner**

366 All right, now it's my turn. So, the last topic is about circular product design. I also do have
367 some slides. Umm, are you now able to see the slides or is it better if I just walk you through
368 it?

369

370 **PdH**

371 Yeah, it's better to walk me through.

372

373 **Annelie Sophie Steinbrenner**

374 All right. So, umm what I did is I turned to literature and what I found is a model by Den
375 Hollander, who came up with eight different design strategies all belonging to 3 major goals.
376 The first goal is to design for long use. The second goal is to extend the use of a product and
377 the third one is to recover.

378 I think the strategies for the long use are easily understandable. You can design either for
379 emotional durability or for physical durability. Then for the second goal of extended use,
380 you can either design for easy maintenance, easy repair, or upgradability. For the last goal of
381 product recovery, you can design for recontextualization, refurbishment or remanufacturing.

382 So my question would be, how can AI help to realize these design strategies? So, where's the
383 role of AI and where does it come into play?

384
385 **PdH**
386 So I think as was mentioned by Lena number 2.
387 The use case that I just mentioned I think applies to what you mentioned in one of those
388 design strategies. I'm not entirely sure which one it relates to, but I guess it's about this
389 component optimization as I call it. Umm which is, you know, good for use. So that people
390 keep the product right. So they like it and they keep it. At the same time it balances that with
391 the extent to which the product can be remanufactured or taken apart and used for other
392 purposes.
393 Then another use case or use of AI in this context, for instance, could be in... Well, what I
394 found fascinating was the emotion. What did you call it? Emotional attractiveness of the
395 product or something like that.
396
397 **Annelie Sophie Steinbrenner**
398 Emotional durability, yes.
399
400 **PdH**
401 Yeah, yeah, yeah. So, here, perhaps AI together with other technologies could play a role in
402 the sense that depending on the product, you could perhaps use AI to offer more, let's say
403 personalization options like changing the color or changing the way the product looks or
404 feels.
405 And then perhaps by using AI you can make the product more flexible without replacing it.
406 So people can change the looks of the product. If they are bored with the former version
407 they can keep it more attractive for themselves. Uh, so that I think is one use case that came
408 to mind.
409
410 **Annelie Sophie Steinbrenner**
411 Yeah, that sounds good already. So maybe it makes sense to go one after the other through
412 the different design phases.
413 So, what I already found is that AI can definitely have a role in ideation and concept
414 development. So, for graphic inspirations, for instance. Do you see the role of how this can
415 also be applied, not for design in general, but specifically for circular design?
416
417 **PdH**
418 Yeah, let me think about it. Well, I think that in an ideal world your new product ideation
419 would already take the future circular use of its components into account, right? So that
420 should be ideally a design criterion from day one. So, I guess AI could help, perhaps to say
421 OK, here's a new idea. How could that be used once this product is end of life? How could
422 we use it for other purposes. So that I think could be a nice example to have this sort of
423 circular by design principle already in your ideation, if that makes sense.
424
425 **Annelie Sophie Steinbrenner**
426 Yeah, makes sense makes total sense.

Coming to the next point of the design phase would be prototyping. What I read here is that you can obviously use AI for faster iteration cycles and for faster prototyping, and this has the potential to minimize waste in terms of resource usage. Would you agree with that?

PdH

Sure, sure. Yeah, absolutely, yeah.

Annelie Sophie Steinbrenner

OK. The second AI application of prototyping which I found is, umm, a sensitivity analysis to predict possible failures and downtime. So here, could AI also help?

PdH

Yes, I would agree. And yes, there are also new ideas here as well. I mean, I'm not sure if it's applicable to what you're saying, and you will be the judge of that. An example where we see this happening is in pharmaceuticals where AI's used for simulations where you can already try out new protein structures, new molecule structures and see to what extent they are similar or different. And to predict to what extent they, you know are effective against the virus or bacteria.

I would imagine that you could also use other simulations for other types of products. I mean, I know one example from... You know like Samsung or similar companies that produce electronic equipment like televisions, right? Not Samsung but another company. They are using AI to, you know, to figure out what is the best way to. configure a printing board. You know the boards that you find in equipment with all the chips and other electronic components on them. And the design of such a chip is a very complex puzzle to solve because it's something that must be easy to manufacture, but again, from a sort of recycle point of view, it should also ideally also be designed to maximize the product lifecycle and recycling of that. So, I think AI's used as a as a tool to simulate the design of that and to see how it would work out if the design need to be created in that way.

Annelie Sophie Steinbrenner

OK. Understood. That makes total sense. That's a great example. Coming to the third phase, which is material selection. What I found is that especially for material circularity and waste reduction, AI could be useful. Can you elaborate on that?

PdH

You know, it makes me think of AI. This is still experimental, but where you show picture of your refrigerator and AI detects that you still have eggs and you have some milk and you have some whatever flour and then it suggests what you can make from those materials. So that relates perhaps more to one of the former categories that you mentioned.

But I was also thinking of examples where AI is being used to find equivalent material. So maybe you're used to using steel for some component in your product. But AI could help you to using, for instance, scientific research to find alternative materials.

469 Or to even going further. Similar to the example that I mentioned, in pharma there are also
470 now examples rising at NASA. You know, the space agency they are using generative AI to
471 create new. I don't know what they call it. Compositions of metallurgy, I think is the word.

472

473 **Annelie Sophie Steinbrenner**

474 I've heard of that. Yes, yes, very interesting.

475

476 **PdH**

477 So that would be an example.

478 **Annelie Sophie Steinbrenner**

479 Okay, and last question, before we let you go. Let's talk about monitoring and tracing. So
480 this goes into the direction of predictive maintenance and I wanted to ask you whether you
481 would see digital twins as something which is related to the design phase here? I think AI is
482 very important to analyze real time data and to predict when a product needs to be
483 maintained or refurbished or remade and which also in a circular way extends the product
484 life cycle. Do you have some insights there?

485

486 **PdH**

487 You know to do predictive maintenance, you need indeed real time data as much as possible.
488 Fine grained center data, preferably. You know the higher the quality, also the freshness of
489 the data and preferably real time, the better your predictive maintenance accuracy will be.
490 And one way to implement that is indeed to create digital twins of a product that is being
491 used in operation and business.

492 And then you said digital twin to collect to bring all the data together. This data is the
493 foundation for your AI to enable predictive maintenance. However, the digital twin is about
494 a product in a certain business context in a certain operating condition. But earlier in the
495 process, during the design manufacturing of that same product, you would also find benefits
496 in having a digital twin. But then in a different way because you want to use sensors to
497 assess the quality of the way the product is being manufactured or maybe you want allow
498 simulation of the product.

499 Long story short. Recognizing that during the life cycle of a product, you know from
500 ideation to design, to manufacturing, to distribution, to usage, to destruction or reuse or
501 whatever you call it. During all those phases you have data that you collect about the
502 product and ideally there would be a single digital twin that sort of travels along the life
503 cycle with the product. And that helps to create and maintain products. And anyway, maybe
504 that to a certain extent is hopefully an answer to your question.

505

506 **Annelie Sophie Steinbrenner**

507 Well, definitely, I think I can take a lot of that.

508 I think we're already over the time.

509

510 **PdH**

511 Alright, yeah.

512
513 **Annelie Sophie Steinbrenner**
514 So therefore I want to say thank you so much for your time and also talking for the other
515 Lenas, it was great having you here today.

516
517 **PdH**
518 My pleasure.

519
520 **Annelie Sophie Steinbrenner**
521 One last question, so I did a transcript. I wanted to once again ask for your permission. Is it
522 possible for us to take that transcript and to get information out of that transcript? And also
523 is it possible to name your name in our thesis?

524
525 **PdH**
526 No, that's fine. That's fine, but the only thing I would like to ask you is if you're quoting me
527 directly, then please send it to me for validation.

528
529 **Annelie Sophie Steinbrenner**
530 Yes, that's perfectly fine.

531
532 **PdH**
533 That's the only question and also I would appreciate a copy of your thesis once it's ready, if I
534 may. That that would be interesting.

535
536 **Annelie Sophie Steinbrenner**
537 Yes, yes, of course, of course.
538 So thank you once again and have a nice day.

539
540 **PdH**
541 Thank you. Good luck. Bye, bye.

Appendix D6. HK's interview transcript

Lena Sophie Thielmann

Hello [REDACTED], thank you very much for taking the time to talk to us today. Would you please start by introducing yourself?

HK

Yes, of course, I would love to. I've already gained several years of experience in the field of circular economy and am currently working for a consultancy where I can specialize further in this area.

Lena Sophie Thielmann

Okay, thank you very much, I would just say I'll start with my topic.

I had already touched on the topic of collaboration in our written contact, because I saw in the research that collaboration is a super essential factor for closing the loop at the end, and I decided to concentrate on cross-sector collaboration.

That means, for example, collaborations with companies among themselves, but also companies with the public sector and with society. So collaboration in every sense of the word plays a central role in the circular economy and I then thought to myself, what is the current situation?

HK

Mhm.

Lena Sophie Thielmann

I came across these 10 barriers, so there are many more, but I read that AI already has certain points of contact with these 10 and could help to overcome them. The idea would be to perhaps go through the 10 and see what you think based on your experience. What is their real significance for the circular economy? So how do you currently see it?

Because they are purely theoretical barriers. And how do you perhaps see the connection point that AI could have so that it can then be placed on the matrix?

HK

With pleasure.

Lena Sophie Thielmann

Okay, great. The first barrier is the temporal dynamics of the technology. This means that we can see that there are currently major differences between the various partners in the status quo of their IT systems, but also in the development behind the IT systems. So it is more difficult to unite the individual partners because there are completely different starting points for linking them.

HK

44 Mhm.

45 So when we talk about IT, the blockchain immediately comes to mind when I think of the
46 circular economy.

47 And I think the IT level between the various companies is as low as possible, because
48 everyone is at a very low level. But as such, for the circular economy, I would put it on the
49 first line from the top, i.e. medium importance. Exactly.

50

51 **Lena Sophie Thielmann**

52 Mhm and AI has impact possibilities, as you just said with blockchain?

53

54 **HK**

55 Yes, definitely, I'm just thinking about what it looks like in general in terms of AI. Yes, I
56 think it's actually quite well placed there, if not a little further to the left. However, if
57 everyone's stance is the same, the chance of acceleration should be extremely high. So it's
58 very well placed there.

59

60 **Lena Sophie Thielmann**

61 Great, then the second thing we have is different operational and corporate practices, which
62 simply means that the planning focuses of the individual cooperation parties are different
63 and are also simply prioritized differently.

64

65 **HK**

66 I'm just reading through it again myself. Yes, I would put that even higher than the 1, i.e. in
67 the middle of the upper third as far as Circular Economy is concerned and as an AI
68 acceleration chance? I would also put it in the middle of the right, i.e. exactly mirror-
69 inverted to the right. Yes, because I have the feeling that if everyone were to work on the
70 basis of technology, it would of course have a great advantage for the circular economy,
71 because synergies can certainly be created. But it will also certainly help with the
72 differences in the companies, so AI can certainly support that, and in that respect it also has
73 a big impact on acceleration.

74

75 **Lena Sophie Thielmann**

76 Yes, thank you, then we have the different monitoring or performance tracking of the
77 individual parties themselves, i.e. that different KPIs are set, for example for companies and
78 public institutions, which can hinder cooperation.

79

80 **HK**

81 I would. Also add to #2.

82

83 **Lena Sophie Thielmann**

84 Great then Risk of information loss this mainly means that nowadays there is a lot of
85 uncertainty about what information really needs to be passed on and how is this information
86 handled?

87

88 **HK**

89 It is also extremely important for the circular economy because the loss of information
90 shouldn't actually happen, you always have to know, for example, about the content of the
91 material data passports or similar, which now also has to do with the Eco Design Directive,
92 for example. That has to be a given, so it's very important for the circular economy. And I
93 would see it to the left of the 3. Or I'd like to move it to the right of 2 as I think it's more
94 relevant.

95

96 **Lena Sophie Thielmann**

97 Great, so the lack of transparency is simply that the individual cooperation partners are
98 hesitant about what they share and disclose, because it's not entirely clear whether it's
99 anonymized or not, or how is it handled? Where exactly is it stored, etc.?

100

101 **HK**

102 Also in the upper third. I would see that in the middle for AI acceleration opportunities.
103 Because I think in general, many people are hesitant or the industries are hesitant when it
104 comes to new technologies and data transparency. And I think that's true regardless of
105 whether the problem exists or not. So now the barrier 5 exists, I think either way the lacking
106 AI adoption today would still perhaps be the reason for the barrier, because the possibilities
107 of AI here are rather limited regardless of that. So it has an impact, but I think it's also
108 separate from each other and therefore independent in the middle.

109

110 **Lena Sophie Thielmann**

111 Okay, great thanks, then we have the interests of the individuals in the different sectors, so
112 earlier it was performance tracking per se, so to speak, but here it's also about pursuing
113 different goals internally.

114

115 **HK**

116 Mhm.

117

118 **Lena Sophie Thielmann**

119 For example, everything can go in the direction of sustainability, but the focus is on other
120 topics. Is it an obstacle for Circle Economy or do you see it differently?

121

122 **HK**

123 Oh, I would even put that at the top of the list for circular economy, because that's a major
124 problem. Therefore, even above the 4 that we have already placed at the top, because I think
125 a major problem is that I don't think people have a consistent picture. It's not without reason
126 that Mr. Kirchherr, a McKinsey consultant or partner for circular economy, has published a
127 paper on the conglomeration of hundredfourty definitions of a circular economy or
128 something like that. So I think that's pretty important. AI acceleration opportunity let me

think about it again for a moment. I would now also see it at 5, at that level. I don't see it as an accelerator.

Lena Sophie Thielmann

Do you think it's more of a people problem?

HK

Mhm. I would describe it as a mindset problem. Exactly the same as with sustainability. For example, sustainability is not a circular economy and vice versa, so I think it's a mindset issue, it's all very confusing for many people.

Lena Sophie Thielmann

Yes, that's right, okay, then we have point 7, the lack of standardization of a system for the performance management of the collaboration itself. So how is this collaboration made measurable at the end of the day and also communicated to the individual parties? So now, for example, a private company has worked together with a public institution. And in order to measure the effectiveness of this cooperation, there has to be some kind of tool or some kind of data basis, a consensus, on how to make it measurable, and there is simply a lack of a general basis these days, but probably also simply the will behind it.

HK

I don't know if this contradicts your research objective, but I would place it at the bottom right, so I think it has a high chance of AI acceleration, I think there is potential here. But I'm not sure how such performance tracking or management could be relevant for the circular economy. So not in the collaboration between companies I think. We're facing a different problem today, which is that companies are generally simply not prepared to enter into cooperation at the level of the circular economy. You can perhaps pull that up a little higher under the first line, but that's about it.

Lena Sophie Thielmann

Okay, yes, very interesting. Then we have approaches to risk management under point 8. This simply means that the different parties involved in the collaboration have different perceptions of risks and also perceive other issues as risks and react even more sensitively to them accordingly.

HK

I would put it relatively high for the circular economy, because the circular economy also has the potential to minimize risk. Because global supply bottlenecks could be avoided if local circular economies are set in motion. In this respect, if the same risk is understood between parties, I think it has a good impact. And I would put the chance of acceleration next to #2 because the whole risk assessment or risk and decision calculations, I think there is a lot of potential there.

172 **Lena Sophie Thielmann**

173 Okay, and then the penultimate point is the low demand and acceptance for ecologically
174 superior technologies, especially now in relation to developing countries, which simply have
175 a completely different focus on their economic situation and are currently simply not
176 interested in participating in sustainable projects or investing in them.

177
178 **HK**

179 Yes, I'd also like to put it at the top of Circular Economy at 6, so for now at the level of 6.
180 And with AI acceleration opportunity, I think I would actually leave it where it is, because it
181 has a high impact on the circular economy, what people think at all, what the understanding
182 slash demand and acceptance is. And I said that earlier, so I think it's a mindset
183 thing/problem and I don't know how AI could accelerate that.

184
185 **Lena Sophie Thielmann**

186 Yes.

187
188 **HK**

189 In this respect, I see it as irrelevant as far as the x axis is concerned.

190
191 **Lena Sophie Thielmann**

192 Yes, I totally understand and then as a final point we still have inflexible policy and
193 structure as an overarching problem in many developments, what is your experience in the
194 circular economy area?

195
196 **HK**

197 So I find, for example, that there are very strange discrepancies in the fact that the People's
198 Republic of China, for example, has somehow included reduce reuse recycle in its latest 5-
199 point plan. I would describe their policy as extremely inflexible in the sense of very
200 undemocratic and therefore not really flexible and extreme structures. But they already have
201 something like that in their five-year plan. On the other hand, we are extremely flexible here
202 in Europe and are now bringing the Ecodesign Directive for Sustainable Product Design
203 Regulation onto the market in the coming years. But again, nothing is happening, so I would
204 almost put it in the middle because the two examples I have in mind go in both directions
205 and that's why I think it fits quite well in the middle.

206 And I would leave it right there, because again, I don't see how acceleration could be
207 generated by AI in any way.

208
209 **Lena Sophie Thielmann**

210 Yes, great, then I'd like to thank you very much and hand over to Annelie, I think.

211
212 **HK**

213 Very good. With pleasure.

214

215 **Annelie Sophie Steinbrenner**

216 Exactly, so to start right in, my research focus is on product design and specifically can AI
217 improve or accelerate the design of a circular product.

218 I've just looked at various design frameworks and have now settled on one. This framework
219 here describes 3 goals, namely designing for long use, then in the middle for extended use or
220 even for recovery. And as you can see, there are a different number of design strategies for
221 each of these overarching goals. For long use, for example, you can design for emotional
222 durability and physical durability, for extended use for things like maintenance, repair,
223 upgrading and for reclamation for recontextualization, refurbishment and reprocessing.
224 First of all, I would like to ask how can AI help to realize the design strategies or even the
225 design goals?

226
227 **HK**

228 Mhm just loose now? What comes to my mind?

229 There are companies, I think Oerlikon or other 3D printing companies, for example, that can
230 build extremely complex shapes using lasers or other metal-forming 3D principles and I
231 think there is potential there, for example. What if I look at this now...

232 Well, I think the recovery of materials. With cars, for example, you have the problem that
233 disassembly is not guaranteed because clips, i.e. plastic clips, are used and you can't separate
234 them from each other, or at least you can't separate them non-destructively. And I think AI
235 could get a lot out of that in product design, i.e. in the design of how the molds are created.
236 And now. Let me just go through the numbers of the design strategies from left to right.
237 I think design for emotional durability is also high. If I understand correctly, emotional
238 durability is that I buy the white cup and I think it's great today and I'll still think it's great in
239 10 years' time, right?

240
241 **Annelie Sophie Steinbrenner**

242 Exactly right. So, for example, like an old expensive leather bag or something, it doesn't go
243 bad and can therefore be passed on from father to son or daughter. So you have an emotional
244 attachment and you actually want to keep it. Or it even becomes cool or vintage if you keep
245 it for a longer period of time.

246
247 **HK**

248 Ok, then I also see there that AI can help to realize a design strategy, because I think the data
249 evaluation alone. If you do market research and collect data, i.e. customer interests, how
250 long products stay with people, how they are passed on and so on, then I think AI can
251 definitely help.

252 Design for physical durability. So it's extremely important that products last longer. But I
253 think AI could perhaps also help here in terms of weighing up how long a product needs to
254 last. In other words, life cycle assessment.

255 For example, at the moment people often make fallacious conclusions. Something like, I'd
256 rather buy an aluminum bottle, I'll have it for 10 years and therefore I won't buy any more
257 plastic bottles. But what if the plastic was a monomer and extremely easy to recycle?

258 And I think there's a lot of potential for AI in calculating all the life cycle assessment cases.
259 Or AI could also provide support there.

260

261 **Annelie Sophie Steinbrenner**

262 Mmh.

263

264 **HK**

265 Now to the middle. Design for maintenance for longer use. Does that mean I hand over the
266 product and it is maintained?

267

268 **Annelie Sophie Steinbrenner**

269 No, so the idea behind all 3 central strategies is that you can see in advance during the
270 design process when the product might break. And when would I need maintenance or a
271 repair at the latest? You actually have to start forecasting and make sure at the design stage
272 that the devices or parts are in stock at the right time.

273

274 **HK**

275 Mhm yes, okay, so I was just on the fence about maintenance, but maintenance, I'm back to
276 that. If you look at predictive maintenance now, it's a super important topic.

277 If you look at production and the production machines, predictive maintenance is of course
278 extremely important in the sense that the products that come out are of course good, but also
279 that you don't have any downtime in the factory.

280 But also later on. I mean, if you sell a washing machine or a dishwasher or a refrigerator or
281 something. For example, my dishwasher broke down 3 weeks ago and if he had told me a
282 week before that "Hey, next week it's very likely that the heat pump will break down, just
283 ask the repairs department."

284 In this respect, I think predictive maintenance and AI, it's a match.

285

286 **Annelie Sophie Steinbrenner**

287 Mhm.

288

289 **HK**

290 Design for repair. I'm struggling with that now. I mean, it comes out of design for
291 maintenance. So it's a consequence of that, so to speak. And to that extent it also has an
292 influence on it, but I don't see how the AI strategy could be applied only to that.

293

294 **Annelie Sophie Steinbrenner**

295 Yes, so that has come up several times now. That the same things, such as predictive
296 maintenance, can probably be used everywhere with these 3 strategies, especially with
297 extended use, and that there are no specific AI differences. So that's perfectly fine and it
298 makes a lot of sense to me that many experts say that the same AI aspects as predictive
299 maintenance are used for maintenance and reparability

300

301 **HK**

302 I think design for upgrades makes sense from the perspective of a company, for a company
303 that also sells the products in turn.

304 So, I've described design for maintenance from the perspective of the end user, the things for
305 upgrading are also partly for end customers.

306 But I think for the business model of a company... When do I have to approach my
307 customers so that I can tell them again "The upgrade is" and to take that into account in the
308 design would be mega cool. But I don't know if that would work.

309 But I think AI for upgradability could also help in product development, data processing or
310 market research.

311

312 **Annelie Sophie Steinbrenner**

313 Mhm.

314

315 **HK**

316 And then on the right point, reclamation, reverse obsolescence. Wait a minute. What is
317 obsolescence again?

318

319 **Annelie Sophie Steinbrenner**

320 Obsolescence. So when practically a product becomes obsolete, the idea of the design
321 strategies is that the product is no longer used in its original or original state. The idea
322 behind recontextualization is that you try to use the product perhaps no longer in its original
323 use, but perhaps in a different use. The topic of refurbishment is simply refurbishment, you
324 can perhaps do more with that and remanufacturing is remanufacturing.

325

326 **HK**

327 Ok this recontextualization I could also imagine that AI helps in the evaluation of what to
328 upgrade or what to upcycle, what to downcycle or now in the decision-making process,
329 whether this is the case at all. Whether I now say it will be taken again directly in another
330 case. Whether I should ultimately remanufacture or recycle, etc.?

331 I think AI could certainly provide support in the decision-making process.

332 Design for refurbishment measures was refurbishment?

333 I think that's another consequence of 6, recontextualization?

334 As I've already said, AI can also help with the decision as to whether it should be
335 refurbished or not. I see potential there.

336 And design for remanufacturing. There too. Although I'm now most critical of
337 remanufacturing. Critical of the product that is returned to the customer, because in my mind
338 remanufacturing is often associated with the warranty, because it really is returned to the
339 customer in its original condition.

340 For example, if we have an engine that is remanufactured, then the pistons are milled out
341 again and so on, and there is a liability involved. I also see potential in the testing of such
342 products, for example, and in the decision beforehand.

343

344 **Annelie Sophie Steinbrenner**

345 Mhm, okay, okay understood, that means just very briefly again for me to summarize.
346 So recovery, did you think the greatest opportunity for AI lies in the decision-making phase
347 or decision-making?

348
349 **HK**

350 Mhm.

351
352 **Annelie Sophie Steinbrenner**

353 By extended use, did you mean mainly predictive maintenance across all 3 sub-strategies?
354 And by extended use, you meant life cycles assessment, right?

355
356 **HK**

357 Mhm on the point 5, upgrading I wouldn't say predictive maintenance but predictive
358 upgradability. Or predictive potential.

359 Annelie Sophie Steinbrenner

360 Yes, yes, okay understood.

361 I would like to ask you again about monitoring. Do you think AI could also help with
362 monitoring, i.e. tracability, also in relation to a digital twin, for example, to find out when all
363 these things like maintenance, remanufacturing or something like that need to be addressed?

364
365 **HK**

366 Yes, I think it very much depends on what kind of products we're talking about.

367 If we're talking about machines that have a high throughput or manufacturing machines in
368 general. I can totally see that. A digital twin also makes a lot of sense for other reasons.

369 But if you're talking about design for circularity. Let me give you an example. An office
370 desk doesn't need a digital twin or a Shadow.

371 I think it makes sense for expensive products with a high degree of utilization. On an
372 industrial level. I mean, you could somehow buy an extremely expensive suitcase, an
373 extremely expensive handbag, but you don't need a digital twin for that. You don't need the
374 real-time analysis. But with other products, yes.

375
376 **Annelie Sophie Steinbrenner**

377 Okay, all right. I think that fits from my side as well. Then I'll pass the floor on to the other
378 Lena. Thank you again for your time and it definitely helped a lot.

379
380 **HK**

381 Great, I'm glad.

382
383 **Lena Maria Pertz**

384 Hello, I'm the other Lena, I've dealt with the topic of circular business models and would
385 also like to share my screen very briefly and show you briefly what I've found so far and
386 see if we can go through it together. In my research, I found out that there are 5 Circular

Group Part

387 Business Models that you can see on the left and on the right side is shown what the value
388 chain of a Circular Business Model can look like. The arrows are indicators of processes that
389 make up this circularity, such as recycling, upcycling, upgrading, repair, then sharing
390 platforms and all that, and I took a look at the processes and broke them down here on the
391 next slide. I have found 6 different business model components and would now like to go
392 through them step by step with you and discuss an assessment of AI use cases for each one.
393 So if you want to read through it for a minute, also really fine and then you are welcome to
394 start, if you are perfect, then we will do it that way.

395
396 **HK**

397 Perfect, so a take back system would be closing the loop, wouldn't it?
398 Okay, so with the first one I would now validate the two use cases from my point of view,
399 makes a lot of sense, but I would like to think briefly about whether I can contribute more to
400 it afterwards. I think it's a good point with route optimization, but I think it's also about
401 finding where are my route optimization? So optimization is, have my locations and how do
402 I optimize the route in between? For me, the question is, where do I put take-back locations,
403 for example? So, in the end, exactly the same decision, why is a factory built for the car
404 manufacturer and built there, but not built here? Built and there it is, I think the same thing,
405 so why such a site assessment for them?
406 Would you use the Take Back System for the local Tec System?
407 I might see that in the step before.

408
409 **Lena Maria Pertz**

410 Ok, so to speak, that you might try to set the Take Back System location efficiently, so that
411 all EOF products can be collected as quickly as possible?

412
413 **HK**

414 Yes, exactly, so that certainly makes existing things to take, but I think there is also potential
415 to create new spaces and build new logistics centers or something.
416 Point 2 they have is about maintainance, repairs and upgrades and maximum user
417 friendliness.

418
419 **Lena Maria Pertz**

420 In an interview, I have not yet been able to familiarize myself with the fact that you could
421 theoretically already use chatbots or virtual systems, because you can, so to speak, when
422 these predictive maintenance analyses are run, from the vendor, I say, who then somehow
423 has to inform the customer hey, we somehow have something detected, the machine will
424 most likely fail in the next 2 weeks.
425 We come by and then do service so that you could theoretically integrate the chatbots for
426 these ready-made processes.

427
428 **HK**

429 Yes exactly, I see the point of agreeing but I do. Nevertheless, I now estimate that the

business modell will only be partially useful in society, because if you look at the population now - the age distribution, for example now in Germany, then I think the majority are simply not interested in chatbots. This will happen over the years, but not at the moment. In this respect, I see it as it stands the point, I think this is just such an add-on for, I mean, there are enough companies that offer chat bots, that would be an idea for them, so to speak, but I think that was not a single business model.

Lena Maria Pertz

Yes, definitely not, yes yes, that's quite funny to listen to. Chatbots so I've already heard in front of several people, yes you can definitely do it and it's also good, but now also as I said from you or from another interview partner that chat bot now not the trust or also that they have the performance that they seem to have to say yes no one wants from Welcome Rande, which I've already figured out.

HK

Yes, I'll find something maybe very briefly back the one because of chatbots. Bots I also find that is also often related to the quality of products so I find chatbots so this or circular products are extreme at the moment, so now for the end consumer, if you look like that now. If you take a quick look at Consumer, for example, I think it's extremely high-quality and extremely expensive and. I think I'm still on the track that I say, if I have expensive products, then I want to have a real customer service and not a chatbot, but that's just our culture or my view of things. I think if you're in China now, that's again or so I lived in China for a long time, so I think it doesn't matter there again, so there's customer service. Important, but not now, so it doesn't really matter in that respect.

Lena Maria Pertz

Yes, it's really important that you also look geographically, what the customers might prefer in such cases, that's okay.

HK

Thirdly, optimal use of product by customer to training and consulting. Mhm, productive analytics, transport, customizing. Yes me too. But I see the point there too, I think. But although I see it, I would even see it very strongly, because I think. As a business model, you can simply stay much closer to your customers and much more. We are no more yes service sell than if you call in order cyclically or at cyclical intervals again and again and say so bright how does it look?

Lena Maria Pertz

Top each one maybe goes a little bit with the sixth point, because, then we can also look at it directly, a little bit hand in hand I have now called Customer Intelligence, what I got out a bit in research is that this co-creation between customer and walls or Sella is very important.

Group Part

472 In the circle economy, that you also involve the customer with you, that includes the
473 feedback and I think I also have a chatbot there, among other things.
474 But also the sentiment analysis, that you can include the feedback from the customer in the
475 following processes, so to speak, so that you can send the customer feedback directly
476 hopefully automatically with AI to the places where the business catch is also located, i.e.
477 where the feedback can be implemented directly, which is a bit part of point 3.

478

479 **HK**

480 Exactly, yes, I see myself on the same level, I also think it's good.

481

482 **Lena Maria Pertz**

483 Okay, yes, I'll write it down.

484

485 **HK**

486 Automated end of Rental Suggestion so maybe offer to the customer or say like hey, now it
487 does for you so maybe sell it to him just as if? But it makes sense to switch now. I mean, it's
488 kind of like one. Something like check 24 for energy or mobile communications and so that
489 you say Hey both, we have we have your data and we now know that leasing makes much
490 more sense for the other.

491

492 **Lena Maria Pertz**

493 Yes, yes, that's right, so I'd like to go into a little bit with the second point about Customerid
494 an Strategies, I think, how you theoretically propose, on the basis of the data that he
495 generated in the last leasing phase, hopefully to him Future, I'll say with it pushes in a bit
496 indirectly.

497

498 **HK**

499 Whereby now means that my point that I made at the beginning was really more from the
500 service point of view.

501 Not product in have nen company so like Check 24 really that the look of exactly yes I
502 would have now I would have said now.

503

504 **Lena Maria Pertz**

505 Ok, comparison portal, so to speak.

506

507 **HK**

508 Mhm Sharing platforms customers

509 Yes, I would now also confirm, I also see.

510

511 **Lena Maria Pertz**

512 Okay, great yes, then I would say first of all thank you very much, if you can think of any
513 other use case on Top Of your Head, I am of course happy too if not, that was also super
514 helpful.

515
516 **HK**
517 let me think about it for a moment, I had something in mind, but I think I already had that
518 earlier. Once called. I think what the simplest guarantee is for Uwe yes so now, now it's a
519 mix of 2 topics, but this influence could be in the sense of circular business model could also
520 be just that you keep the product designs. Created by an artificial intelligence. So the one,
521 for example, so I can just get it from so I know it from is a rocket engine. Drive that was this
522 use case, what I think with friend, me from Oerlikon, they have there. It's not Oerlikon, I
523 might try to send you that slower, but they don't do anything else than you give me input, for
524 example the cup and the saws, he only gets this button but does it?
525 Organically have it in organic form and if you can do that, you can also say to yourself me
526 Hey. The others, the topics that we mentioned earlier, and I think this could also be done as
527 a software service business model, so if you now have a CAD program to design or develop
528 products on the computer, like autocad Inventor for example.
529 I would also see that as a bit of a hotel, that you simply accommodate developers and offer
530 them, so to speak, circular bids that they can simply automatically incorporate into the
531 product designs.
532
533 **Lena Maria Pertz**
534 Okay, so it's a bit of a marketplace for designers?
535
536 **HK**
537 Exactly.
538
539 **Lena Maria Pertz**
540 That would mean that you can run different automation processes for those of their provider
541 and then, so to speak, through their provider, which then probably even drag subscription.
542
543 **HK**
544 Yes, that would be perfectly clear.
545
546 **Lena Maria Pertz**
547 Yes, okay nice perfect that sounds good yes I think, then we are finished from my side for
548 the time being, thank you very much for your time and your inputs.
549
550 **HK**
551 Absolutel

