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

BUILDING BLOCK B: CIRCULAR BUSINESS MODELS

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This paper investigates the transformative role of artificial intelligence (AI) in the circular economy (CE), emphasizing one of the three core building blocks: optimizing circular business models. Highlighting CE as a sustainable alternative to the linear economy, the study develops a conceptual framework to underscore how various AI applications positively influence each business model innovation, promoting circularity. The framework aims to guide managers in transitioning to circular business models while sustaining a circular advantage with the help of AI. The study underscores AI's potential to drive innovation and efficiency, reshaping economic models in an environmentally conscious manner.

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. 2022). 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 Saccani (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 Turning 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 Turning’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

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 assists 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, Ntoutsi 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.

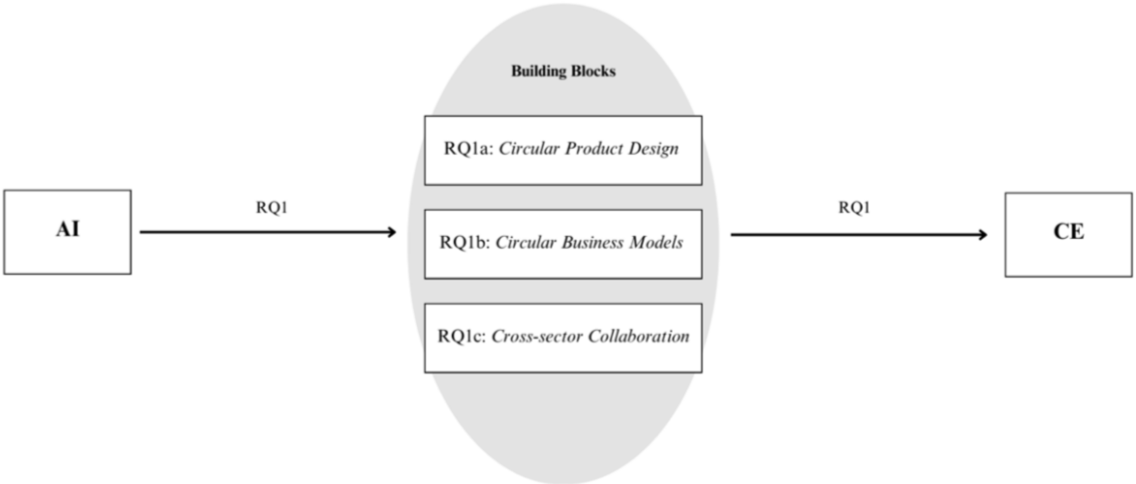

Figure 1. Comprehensive research model (Source: Own illustration)

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 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 200

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

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

6.1 Introduction

“We need to become more efficient in reusing our resources. . . That’s a big part of our climate-change battle: learning how to use and reuse our resources and make more out of them for the sake of the planet. That’s why circular business models are required in many industries”. On the one hand, the quote by Thomas Gros (McKinsey & Company 2023), CEO and co-founder of circulee, highlights the paradigm shift in how today’s businesses must create, deliver, and capture value to address environmental challenges. Conventional linear business models (LBM) are no longer the ideal way of operating, instead, firms should focus on circular business models (CBM) that aim to increase resource efficiencies, reduce waste, and maintain product longevity (Bocken et al. 2016). On the other hand, Janet Bannister (McKinsey & Company 2023), Founder and Managing Partner of Staircase Ventures, acknowledges the potential of AI as a general transformative force in the business context by stating: “AI is an accelerant; disruption from technology invariably comes, and now it’s coming faster”. Indicating that AI technologies are acting as a catalyst, speeding up the pace of business innovation. By synthesizing the core messages of these two statements, one can hypothesize that the convergence of AI and circular business models is unavoidable, hence a pivotal area for exploration. Only a few researchers have already investigated the potential of AI-based tools empowering circular business models. Hence, a noticeable research gap persists. In specific, practical examples of explicit AI applications enhancing CBMs are notably limited. This displays a challenge as AI technologies progress more rapidly than industries can assimilate, echoing the sentiments of the aforementioned quote by Bannister (2023), besides underscoring the significance of this research. To address this challenge, the research aims to shed light on how firms can leverage different AI capabilities along their value chain to innovate their circular business models strengthening their ‘circular advantage’.

Given this objective, the supplemented research question is: *"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?"*. To examine this research question, the subsequent sections are structured as follows. First, the current literature on CBMs, circular advantage, and the existing landscape of AI applications within CBMs are reviewed. Second, the research methodology will be described, including the data collection, and data analysis. Third, the findings will be displayed, detailing three different types of AI capabilities as well as different AI use cases along four CBM elements. Based on these findings, the derived framework will be explained, focusing on the reciprocal relationship of AI and CBMs. Fourth, the research paper continues to provide theoretical and practical implications. Last, this study will end with a demonstration of research limitations and recommendations for future research.

6.2 Literature Review

6.2.1 Circular Business Models

A business model (BM), as outlined by Richardson (2008), serves as a blueprint explaining how enterprises function. Hina et al. (2022) extend this finding by defining BMs as a simplified representation of how an organization generates, offers, and delivers value to stakeholders. Hence, BMs are made up of three key components: value proposition (states the value a business will offer to customers and other stakeholders), value creation and delivery (entails how value is created along the value chain and how it will be delivered to stakeholders) and value capture (embodies the revenue model describing how value is retained) (Centobelli et al. 2020; Perey et al. 2018; Ünal et al. 2019). Contrasting to the conventional linear business model, which focuses on the generation of economic value through a one-time sale of goods or services (Nußholz 2018), a circular business model is the strategic framework that describes how an organization creates, delivers, and captures value by preserving the embedded environmental and economic value of a product or service in multiple use-cycles (Fraccascia et al. 2019). Thus, the main objective of CBMs is to slow down and/or close resource loops to minimize waste and increase resource productivity (Bocken et al. 2016). According to Van Loon, Diener, and Harris (2021) slowing down activities extend the final product use time (e.g., maintenance and repair services, sharing or leasing) while closing activities extend the material use time (e.g., refurbishment, remanufacturing and resell). This highlights the importance of resource usability, recoverability, durability, and validity as well as novel ways of accessing products and services. Accenture (2020) identified five types of CBMs: *circular supplies, resource recovery, product life extension, sharing platforms, and product service systems*. These five business models exhibit distinct circular motivations in terms of slowing down and closing the loop activities, leading to various implications along the value chain, as defined and illustrated in Appendix B1a and B1b. In sum, within all of these business models waste is no longer a liability that producers pay to dispose but it is rather treated as an asset to strengthen operational and material circularity (Ellen MacArthur Foundation 2014). Organizations with a strong focus on operating within the circular principles combine hybrid forms of these circular business models as they mutually reinforce one another (Bocken et al. 2016).

6.2.2 Circular Advantage

The concept of a ‘circular advantage’ has been highlighted by Accenture (2020), emphasizing the transformative potential of the CE in reshaping business models, and creating a competitive edge for companies. Accenture‘s research has identified that applying CE principles and new technologies can transform how companies, create, deliver, and capture value, posing a serious threat to established incumbents. This competitive edge gained by these companies is termed ‘circular advantage’, signifying the strategic benefits derived from innovating for both resource efficiency and customer value. On the same note, the Ellen

MacArthur Foundation (2019) suggests that businesses achieve a circular advantage by going beyond just using resources efficiently. This means they aim to not only reduce waste but also to create outputs that can be valuable inputs for others in the economy, focusing on increased asset utilization as well as extended product lifespans. Vladimirova (2016) and Lewandowski (2016) echo this sentiment, defining circular advantage as the competitive benefits derived from adopting CE principles, focusing on minimizing waste, and maximizing resource value through recycling, reusing, and remanufacturing. In essence, one can conclude that circular advantage encapsulates the strategic benefits gained by businesses embracing circularity along their value chain resulting in increased resource efficiencies, improved waste reductions, and stronger product longevity, hence these three parameters are selected to measure circular advantage in the aforementioned research question.

6.2.3 Artificial Intelligence in Circular Business Models: Current Landscape

Regarding CBMs, few scholars have emphasized the pivotal role of AI technologies in navigating the complexities of circular value chains. For instance, Dubey et al. (2020) highlight the synergistic relationship of big data analytics and AI to support CE adoption, correlating with enhanced organizational performance. In addition, De Souza et al. (2021) illustrate the practical application of AI in supermarkets, where IoT and AI enable dynamic pricing and efficient refrigeration, reducing food waste. Moreover, Pellegrino, Stasi, and Wang (2023) highlight the use of AI in interpreting consumer attitudes and behaviors to contribute to CBM development. The study by Sjödin and Parida (2021) underscores the competitive advantage gained by companies collecting valuable insights through AI-driven business models. The authors found that applying AI in conjunction with CE principles can revolutionize industrial firms in creating, delivering, and capturing value more sustainably (Chauhan, Parida, and Dhir 2022). Despite these opportunities, challenges lie in successfully integrating AI in CBMs, with the need for a detailed outline to guide the transformative journey along slowdown-/ close-loop activities.

6.2.4 Development of Research Gap

The research landscape surrounding the integration of AI within CBMs remains an evolving domain, marked by a noticeable gap in the existing literature. While some scholars have explored the potential synergy between CBMs and AI, there is a scarcity of comprehensive studies that bridge theory with practical application cases. The extant literature hints at the promising effects of AI, suggesting enhanced positive outcomes of CE practices within CBMs. However, the current body of research falls short of providing robust empirical evidence and in-depth analyses of actual AI use cases within CBM-specific business activities. The dearth of such empirical validations hampers a comprehensive understanding of the practical implications and challenges associated with the consolidation of AI in CBMs. To advance this field, this research attempts to fill this gap by undertaking an in-depth analysis showcasing tangible instances of CBMs and AI working in tandem. The goal of this research is not only to contribute to bridging the theoretical-practical divide but also to offer valuable insights for businesses and researchers seeking to navigate the complex landscape of CBM practices enhanced by AI technologies.

6.3 Methodology

By addressing the research question of understanding how specific applications of AI enhance CBMs to harness a circular advantage, the research focuses exclusively on the technical cycle, any materials that are non-biodegradable, of the butterfly cycle explained in Section 2.1.1. In addition, the research method is displayed in Appendix B2 and will be explained as follows. The first objective was to understand which processes or business activities are exclusively part of CBMs and are not involved in LBMs. As mentioned in the literature review, the atypical LBM processes belong to slow-down-/ closed-loop activities. To identify specific

CBM elements belonging to these two types of circular activities, a profound examination of the value chain of CBMs was conducted. Existing literature has supported this analysis, highlighting different types of CBM elements that are indispensable for firms operating along circular principles. For instance, sharing, servitization, maintenance provision, and use of renewable resources are slow down-loop activities of CBMs which help maximize the value of resources or products in different stages of the value chain (Ranta, Aarikka-Stenroos, and Väisänen 2021). Next, loop-closing activities along the value chain of a CBM include reusing, remanufacturing, and recycling activities of resources (Bocken et al. 2016). Summarizing the findings of a detailed analysis of the value chain activities of CBMs and the input from literature in this field, the following four CBM elements were classified 1) End-of-Life take-back systems, 2) Service for maintenance, repairs, and upgrades, 3) Collaborative consumption and 4) Customer intelligence.

End-of-Life (EoL) take-back systems refer to the processes and frameworks implemented by companies to manage the post-use phase of their products. These systems are designed to responsibly handle products at the end of their life cycle, minimizing waste and optimizing resource recovery (Uhrenholt et al. 2022). The process starts with collecting EoL products, which will be categorized into material streams upon arrival at the take-back hub. The next stage involves the disassembly of the product, where mechanical and manual methods are utilized to break down products into reusable, recyclable, and hazardous components. Subsequently, each material runs through a refurbishment stage which assesses the components on quality control measures. The final stage, disposal, should ensure a responsible handling of non-recyclable components. However utilizable materials retrieved from the initial product can be used for remanufacturing. Hereby, firms can restore used products and extend their lifespan by initiating a new cycle for the product. (Kiritsis, Bufardi, and Xirouchakis 2003; Klausner and Hendrickson 2000).

Services for maintenance, repairs, and upgrades play a pivotal role in advancing CBMs by extending product lifespans and minimizing waste. Maintenance services encompass preventive measures and routine inspections to preemptively address issues and ensure optimal product performance. Repair services involve component replacement and diagnostic interventions, preventing the need for complete product replacement. Upgrade services focus on technological enhancements and performance optimization, integrating the latest features and improvements to extend the usefulness of products (Nußholz 2018). Circular models often include extended warranty programs to incentivize customers to seek maintenance and repairs, contributing to a longer product lifecycle. These services are the main component of PSS models, which redefine ownership structures, and encourage customers to pay for ongoing services, maintenance, and upgrades rather than outright product ownership (Zheng et al. 2018).

Collaborative consumption involves people sharing resources and services promoting a communal approach to utilization and sustainability. The research focuses on two types of this approach: leasing and sharing platforms. Leasing ensures that products remain in one life cycle for as long as possible. This is achieved through an agreed-upon leasing contract, when ended the company takes back the product. Hence, instead of the product reaching its EoL in the hands of the initial consumer, it is reintroduced into the market to a new user. Sharing platforms redefine consumption by offering customers limited access to products for a shorter duration in exchange for a regular fee. While access is more restricted than leasing, sharing platforms maximize product utilization across a wider user base. Hence, extending product lifecycles, minimizing the demand for new items, and promoting collaborative consumption for enhanced resource efficiency (Fraccascia et al. 2019; Jiang and Tian 2018).

Customer intelligence in CBMs involves constant validation of customer needs and identifying customized product upgrade opportunities. Providers employ a co-creation approach, collaborating with customers to ensure service alignment along with changing customer requirements. Next, maximizing product utility for customers through targeted training and consulting services is an important component of CBMs. Regular training sessions inform customers about upgraded product functionalities, ensuring they fully leverage the enhanced features. Additionally, provide hands-on assistance with product installation and offer guidance for the seamless implementation of upgrades. This approach not only aligns with CE principles by extending product lifecycles but also promotes sustainable consumption practices, reducing unnecessary waste through informed and responsible product use (Ünal et al. 2019).

These definitions of the four distinct CBM elements set the foundation of the research at hand. To gather valuable insights the primary way of collecting data was through expert-interviews further details regarding the data collection process and data analysis are elaborated in section 4, titled as Methodology. Hereby, the goal was to match the four pre-defined CBM elements with suitable AI use cases. To enhance the robustness and reliability of these findings, the research adopted a triangulation data analysis strategy by collecting information from additional sources, including research literature, media reports, and company documents. This approach, inspired by Miles and Huberman (1994) and Yin (1994) helped to cross-validate the data. As a result, the research will yield a framework elucidating the reciprocal relationship between AI capabilities and CBM elements to foster circular advantage.

6.4 Findings

6.4.1 Artificial Intelligence optimizing Circular Business Models

This section outlines the recommended use cases identified by the experts, insights retrieved from Appendix D, for integrating AI across four CBM elements, as detailed in Table B3. The aim is to enhance a firm's circular advantage, characterized by resource efficiency, waste reduction, and product longevity.

6.4.1.1 End-of-Life Take-Back Systems

The expert interviews shed light on the multifaceted applications of AI in optimizing EoL take-back systems. MH has captured the potential of AI in take-back systems by stating, “the overall complexity of take-back systems, of integrating a product back into the value chain through ‘reverse logistics’ operations, can be significantly reduced with specific AI solutions” (line 273-275). For instance, MH, DH, and HK highlighted the effectiveness of predictive AI capabilities in forecasting locations where specific waste materials are needed by manufacturers. Rather than consolidating all items in a central facility, DH suggested distributing them to locations closer to the primary demand centers. This improves operational efficiency by strategically locating recycling facilities near regions with the highest demand for recycled materials. In addition, HK suggested that AI could be leveraged for route optimization using matching and clustering algorithms or Support Vector Machines (SVM), a type of algorithm. This approach could enhance the efficiency of collecting and transporting processes of take-back systems, by strategically locating collection points based on real-time demand and recycling capabilities. Moreover, several experts converged on the significance of AI in automated sorting processes. DK underlined the integration of computer vision and object detection, which stand out as key elements for real-time decision-making in waste sorting. This involves employing algorithms capable of recognizing and classifying various materials (e.g., plastics, metals, and paper). TE highlights this sentiment by stating: “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” (line 334-336). One showcase example for this is PortiK, a smart real-time solution for automatic waste analysis by Veolia. The solution improves and optimizes the process of waste sorting by continuously analyzing the composition of waste streams and calculating changes in the purity of the specific waste (e.g., aluminum) (Veolia 2023). It relies on image-based waste recognition enabled through CV paired with object recognition algorithms coinciding with the contribution from DK. This end-to-end solution is portable and can be placed anywhere in the sorting process, whether at the initial stage to characterize incoming waste or at the conclusion to assess the quality of sorted waste (Cuingnet et al. 2022). To conclude, the expert’s insights showcase that AI can optimize EoL take-back systems through optimized locations of take-back hubs, route optimization, and automated waste sorting, exemplified by Veolia's PortiK solution, enhancing resource efficiency and waste reduction.

6.4.1.2 Maintenance, Repairs, and Upgrades

Despite some differences in emphasis, the experts converged on the overarching theme of leveraging AI to enhance resource efficiency, reduce waste, and improve customer experiences by offering additional product services such as maintenance, repairs, and upgrades. The expert opinions from DK, PdH, and HK converge on the transformative potential of predictive maintenance through data analytics. DK emphasizes its versatility, citing applications in various industries, from industrial to energy and automotive sectors. The core principle remains consistent – leveraging data to predict and prevent component failures, leading to resource savings and waste reduction. Similarly, PdH and HK delve into specific AI practices that align with DK’s insights. PdH introduces time-series analysis as a means to predict future events. This involves the strategic placement of sensors, such as radio frequency identification (RFID) tags, on critical components of machines which help to detect anomalies, especially important for manufacturing plants. HK expands on this, by introducing outlier detection algorithms. He emphasizes the data-driven approach in sending autonomous notifications when the pre-defined operating conditions of an equipment deviate from normality. Another example, again from Veolia (2023), is Bob an integrated predictive maintenance unit that serves as an assistant at a wastewater treatment plant. Through multiple sensors, empowered by AI, Bob continuously monitors wastewater treatment machines, analyzing vibrations and detecting anomalies, enabling proactive maintenance. All in all, the aforementioned use cases foster circularity within this CBM element by predicting maintenance needs, allowing proactive scheduling for such services, minimizing downtime, and reducing cost. To take up on the point of proactive scheduling of such services PdH introduced the concept of AI chatbots as a supplementary tool for equipment operators. The focus here is on providing real-time assistance in executing maintenance tasks, whether it involves part replacements or other maintenance procedures. This use case is particularly relevant in scenarios where human-machine collaboration is crucial for efficient and effective maintenance operations. However, HK introduced a cultural perspective on AI in customer service, specifically in the form of chatbots. While acknowledging the prevalence of high-quality and expensive products in the industrial market (e.g., specific machinery or massive production plants), cultural factors may influence this perspective, suggesting that in distinct regions the acceptance of AI-driven customer service might differ (e.g., Asia vs. Europe).

6.4.1.3 Collaborative Consumption

During the interviews, there was a common understanding of the potential of AI capabilities to enhance processes for leasing firms and sharing platforms to foster enhanced customer experience while also increasing resource utilization. PdH highlights the potential for AI in demand forecasting for leasing equipment as it can help to optimize the distribution of leased items, ensuring timely availability, and maximizing utilization. Next, HK introduces the concept of automated end-of-rental suggestions, a dynamic approach that leverages AI to prompt personalized suggestions to either continue the lease or transition to a more suitable offering. Thereby, the firm offers a superior customer experience while also keeping the product in one lifecycle as long as possible. Regarding, sharing platforms DK underscores the significance of recommendation algorithms, enabled through Forest models, in offering customers goods and services matched to prior consumer behavior. Moreover, matching algorithms efficiently bridge the gap between supply and demand, minimizing the need for extensive warehousing as resource utilization is maximized. Hence, the potential of an automated return and swap process could effectively connect people with the things they want. As AI can analyze a diverse set of parameters to create clusters of lessors, lessees, sellers, and buyers to find ideal matches. Next to this, PdH highlights the predictive capabilities of AI, enabling platforms to forecast demand accurately. This functionality ensures optimal positioning of shared resources at locations where they are most frequently needed during peak times, hence indirectly enforcing circular consumption. Furthermore, TE mentioned an example in the context of car-sharing services, emphasizing that strategic placement significantly improves accessibility and overall operational efficiency.

6.4.1.4 Customer Intelligence

The research findings unveil a landscape where AI applications can foster enriched customer relationships within a circular environment. Predictive analytics emerged as a common thread among the interview participants. DK stated that predictive analytics and business intelligence can serve as strategic tools to foster the needed co-creation of buyer and seller in a circular context for both B2B and B2C. Adding to this, PdH emphasized the importance of multilateral communication in CBMs and the potential for AI optimizing it. He mentioned that by automatically storing customer usage data and incoming customer feedback in one repository, prescriptive AI capabilities can support comprehending these valuable insights by retrieving usage patterns and anticipating customer needs before inquired by users themselves. Thus, PdH mentioned that predictive AI capabilities can support creating proactive recommendations for personalized training modules or product upgrades, especially within the manufacturing sector. Complementary, TE has illustrated that AI can help through sentiment analysis algorithms by continuously collecting life cycle data, customer preferences, and user feedback to offer insights that guide decision-making. This can assist manufacturers to focus on aligning with new value propositions, or PSS providers (e.g., leasing or pay-per-usage models) tailoring their offerings to individual customer needs. Fundamentally, these AI capabilities shape how customers utilize their products, aiming to enhance both longevity and efficiency. Moreover, within this CBM element, the interviewees also mentioned the application of chatbots. DK suggested that such virtual agents can be used to engage humans in which NLP algorithms are used to automate answering queries, providing step-by-step instructions, offering on-demand training modules, or automatically flagging customer feedback at dedicated business functions.

6.5 Discussion

To conclude on the research question of how companies can leverage AI capabilities within their CBMs to foster circular advantage along the three parameters of resource optimization, waste reduction, and product longevity, the key finding encompasses that AI integrations have a positive influence on a firm's circular advantage. The comprehension of the research has led to the creation of a framework explaining the reciprocal relationship between AI and CBMs, ultimately fostering circular advantage (Figure B1). The developed framework illustrates that different AI capabilities can be leveraged to optimize CBMs across different stages of the value chain referred to as the *streamlining effect*. Hereby, such AI capabilities act as a crucial tool for uncovering hidden inefficiencies and identifying opportunities for reusing, reducing, and optimizing resources, matching with the fundamental principles of a CE. Structuring the insights gained through in-depth interviews one can identify three different types of such AI capabilities: *perceptive, predictive, and prescriptive*. *Perceptive capabilities* refer to the ability of AI systems to comprehend and interpret information from various sources, often involving the use of sensors, computer vision, or natural language processing. These capabilities enable AI to understand and recognize patterns, objects, and contextual information. Within CBMs the key application of this capability is the process of analyzing images from a waste sorting facility to identify and categorize various materials, ultimately improving the efficiency of recycling operations. In addition, interactions with customers involve chatbots equipped with perceptive AI enhancing user experiences. NLP aids in understanding user queries within CBMs, and sentiment analysis ensures tailored responses, aligning with the principles of circularity by optimizing resource utilization and fostering product longevity through positive customer relationships. *Predictive capabilities* encompass the competence of AI in analyzing historical data and current patterns to forecast future outcomes or trends. They aim to make informed predictions about future events by relying on advanced algorithms and statistical model projections. This AI capability contributes to a circular advantage by enabling resource optimization, waste reduction, and product longevity in EoL take-back systems. Predictive capabilities for forecasting waste, route optimization, and automated sorting facilitate strategic decision-making, ensuring efficient resource allocation and reducing waste in the recycling process. Moreover, in terms of maintenance, repairs, and upgrades, predictive AI capabilities empower proactive scheduling of services, minimizing downtime, and reducing resource waste. The use of data analytics, time-series analysis, and outlier detection algorithms enhances the efficiency of maintenance operations, ultimately contributing to resource optimization and product longevity. *Prescriptive capabilities* denote the ability of AI to not only predict future scenarios but also to recommend or prescribe optimal actions based on the predicted outcomes. This involves providing actionable insights and guidance to users, businesses, or systems to optimize decision-making and achieve desired objectives. Regarding the application of this capability in the context of CBMs, AI-driven demand forecasting, automated end-of-rental suggestions, and recommendation algorithms play a pivotal role in optimizing the distribution of leased items ultimately maximizing resource utilization. This approach not only enhances customer experiences but also contributes to circular consumption by keeping products in use for longer.

By utilizing these AI capabilities within CBMs, firms not only contribute to sustain a circular advantage, but they also gain and make use of additional data and valuable insights about their offerings as well as user behaviors. This so-called *amplifying effect* symbolizes the constant cycle of the enhancement of AI models. Indicating that these positive feedback loops facilitate an iterative refinement of AI technologies as stated by Agrawal et al. (2018, 34): "The more the AI is used, the more data it collects, the more it learns, and the better it becomes". Therefore, the more such AI capabilities are utilized, the more they enhance automated data analysis and decision-making processes within CBMs collectively resulting in increased resource optimization, minimized waste production, and extended product lifecycles, nurturing a firm's circular advantage. Overall, AI capabilities foster the virtuous cycle supporting and enhancing CBMs to achieve circular advantage by improving the way firms create, deliver, and capture value in a circular environment.

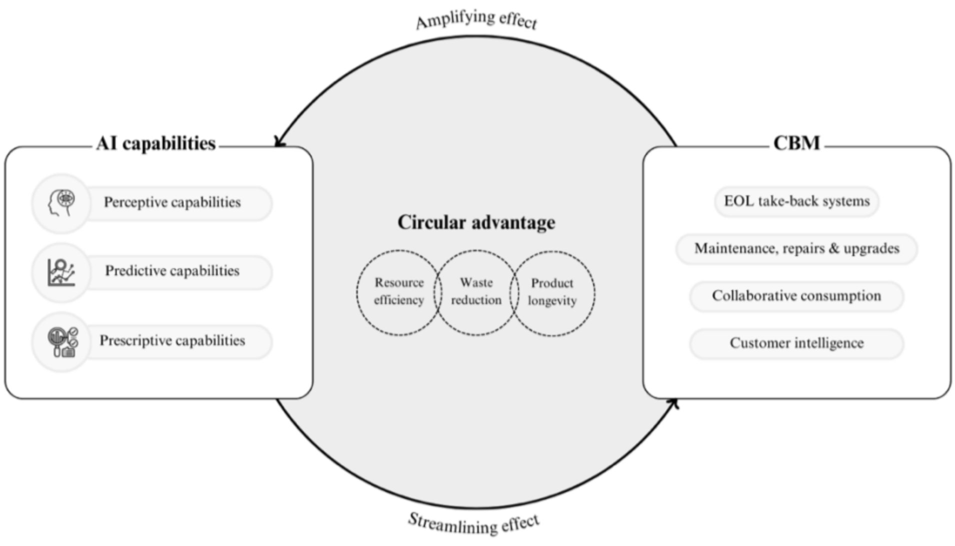

Figure B1. The reciprocal relationship between AI capabilities and circular business models to empower circular advantage (Source: Own illustration)

6.6 Theoretical and Practical Implications

The study contributes academically as follows. It enriches different literature streams, including CE, CBM, and AI. Especially adding insights to the combined effect of these notions which is not commonly examined yet. This study provides a novel framework explaining the reciprocal relationship of utilizing AI within CBMs to increase circular advantage. Hereby, one can gain an increased understanding of how circular players should innovate their CBMs by utilizing AI, businesses can drive economic, environmental, and social outcomes for themselves, their customers, broader ecosystems, and the overall economy. This study specifically examines the transformative potential of three distinct AI capabilities, paving the way for new discussions in the literature on AI and CBM. Additionally, the research offers managerial implications and practical insights for any kind of stakeholder along the circular value chain (e.g., data analyst, business manager, supply chain manager, manufacturer, etc.) by synthesizing diverse perspectives on the integration of AI within CBMs to gain a superior circular advantage. The definition of perceptive, predictive, and prescriptive AI capabilities within CBMs provides these stakeholders with an understanding of possible use cases and their potential to implement AI-driven value chain innovations to work towards a circular future. For instance, while suppliers can enhance supply chains and reverse logistics efficiency using AI within take-back programs, industrial manufacturers operating under a PSS model can boost process optimization and automated decision-making in terms of predictive maintenance services or personalized customer experiences.

6.7 Limitations and Future Research

The research findings highlight a focused exploration of the technical nutrient aspect within the CE framework, as defined by the Ellen MacArthur Foundation (2019), see Appendix 1. The study intentionally excluded the biological cycle of the butterfly diagram, emphasizing a potential avenue for future research in exploring the intersection of AI and biological nutrient business models. Particularly intriguing is the examination of how AI can enhance the cascades business model. Next, as this research has only analyzed how companies that are already operating within a CBM can utilize AI to enhance circular advantage, future research could focus on the role of AI in accelerating the transition from LBMs to CBMs. Due to the prioritization of governmental regulations to support an environmentally friendly business environment, this investigation raises an important question of whether AI can serve as a catalyst for a quicker and more seamless shift into CBMs. Furthermore, the research not only delves into established CBMs but also contemplates the possibility of AI introducing an entirely new business model. This innovative perspective challenges the conventional understanding of CBMs, suggesting that AI may play a pivotal role in the evolution and emergence of novel approaches beyond the existing five CBMs. In a holistic approach, future studies could extend its gaze beyond AI alone, encompassing Industry 4.0 technologies. Due to the importance of a comprehensive technological ecosystem, the integration of IoT, blockchain, cloud computing, and AI along CBMs could be a potential research field. This multi-dimensional exploration encourages a broader understanding of the potential synergies among cutting-edge technologies in reshaping and optimizing CBMs.

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

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 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.

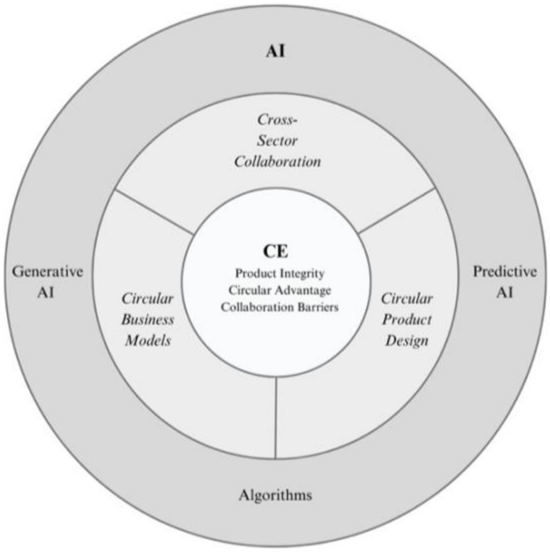

Figure 2. Circular Framework addressing AI’s critical role to secure a more resilient and effective CE (Source: Own illustration)

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 expediates 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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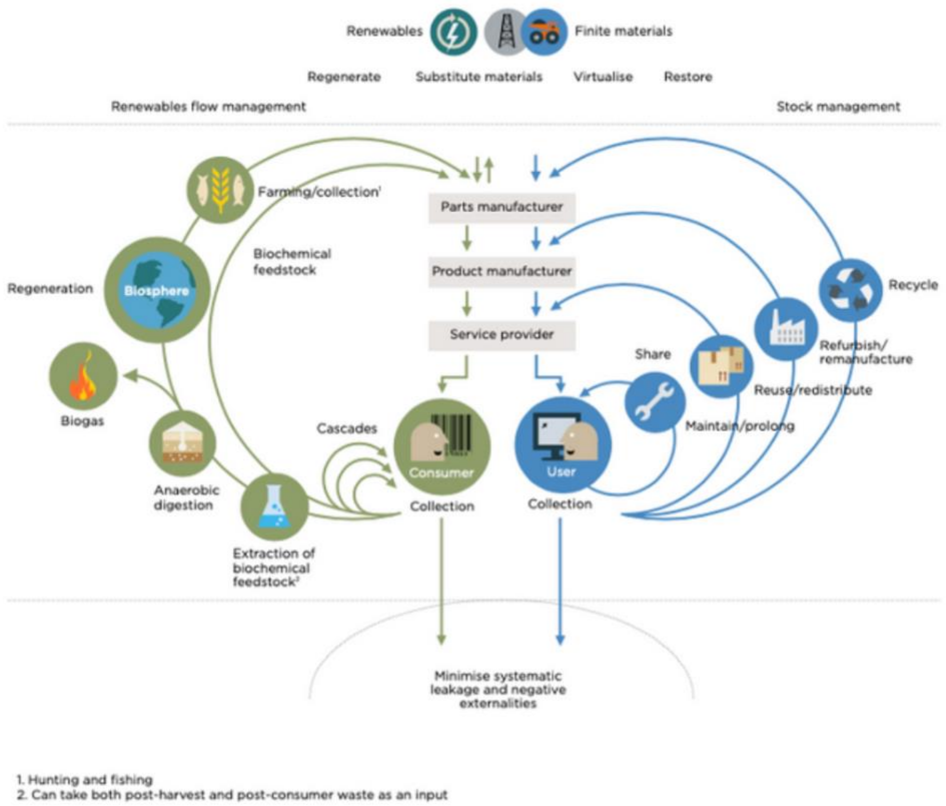
13 Appendix

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*.



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).

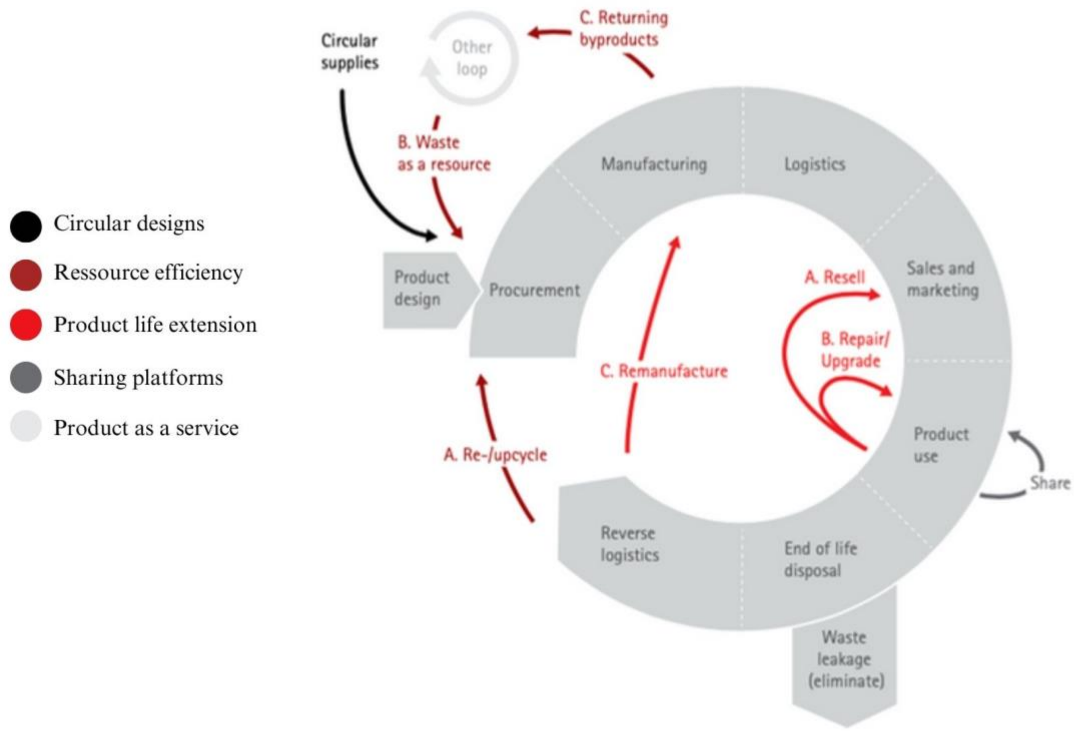
Appendix 3. Expert interview descriptives (Source: Own illustration)

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

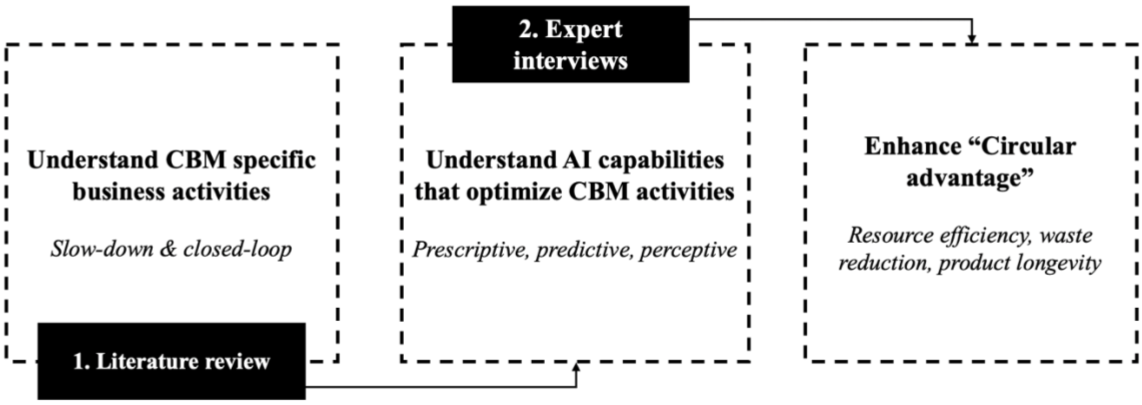
Appendix B1a. Definition of the five circular business models. (Source: Accenture 2020)

Circular Business Model	**Definition**
Circular Supplies	A circular supplies business model focuses on replacing single life cycle production inputs with renewable, recyclable, or biodegradable resource materials. This commitment aligns with circular principles, emphasizing product longevity, repairability, and modular design to prolong the overall life cycle.
Resource Recovery	The core of a resource recovery business models lies in regaining the embedded material, energy, and resources from a product at the end of one life cycle, as it is no longer useful in its current application. This method is regarded as the next evolution in re-(up)cycling, as it can reclaim nearly any type of material at a level equivalent to or surpassing its original quality. Possible approaches include industrial symbiosis for closed-loop recycling or cradle-to-cradle designs where disposed products are reprocessed into new ones.
Product Life Extension	The product life extension business model aims to design products and assets in a way of extending a products lifecycle. Repairability, upgradability, reusability, ease of disassembly, reconditioning, and recyclability are important aspect in the design phase of such business models. Thereby maintaining or improving wasted materials through repairing, upgrading, remanufacturing, or remarketing in a later stage of the product lifecycle gets simplified.
Sharing Platforms	Within collaborative economics, the sharing platform business model serves as a medium of connecting individuals with surplus resources (overcapacity) to those who occasionally need them (underutilization). This innovative approach not only optimizes resource utilization but also cultivates efficient asset sharing within communities or networks, shaping a more sustainable and mutually advantageous ecosystem.
Product-as-a-Service (PaaS)	PaaS business models, also commonly known as Product-service systems, shift the focus from ownership to access, meaning they no longer follow the traditional "buy and own" model but rather offer leasing contracts or pay-for-use arrangements. This entails that customers purchase a product which is owned by the provider, even during usage, and a service which offers ongoing maintenance and upgrades as well as recapture the residual value at the end of the purchasing agreement.

Appendix B1b. Illustration of the circular business models and their dedicated value chain activities. (Source: Accenture 2020)



Appendix B2. Research design for enhancing circular advantage through AI-based CBM integration (Source: Own illustration)



Appendix B3. Key findings on AI use cases for the four CBM elements. (Source: own illustrations)

CBM element	Definition	Value chain position	AI use cases
EoL take-back system	EoL Take-back process includes collecting, transporting, sorting, dissembling, refurbishment, disposal, remanufacture or recycle.	Close loop	• Enhanced locations of take-back centers/ hubs through matching and clustering algorithms and SVMs • Route optimization for collecting and transporting product at their EoL • Visual recognition (e.g., CV) automates sorting process to ensure purity of waste materials (e.g., Portik)
Maintenance, repairs, and upgrades	Maximizes the use of the product through offering additional service for refurbishment, upgrading, maintenance, repair etc.	Slow down loop	• Predictive maintenance enabled through outlier detection algorithms, time series data, sensors, and RFID tags to foresee component failures (e.g., Bob) • Proactive, real-time, and automated scheduling of services through chat bots or customized notifications
Collaborative consumption	The company reclaims the product after specific period of time and renting it to others, can be achieved through leasing or sharing platforms.	Slow down loop	• Use predictive analytics for demand forecasting of leasing products and automate end-of-rental suggestions • Automated pairing of supply and demand for any kind of circular marketplace (e.g., Atomler) enabled through clustering and matching algorithms • Demand forecasting to optimize positioning of shared offers
Customer intelligence	Periodically train customers on the upgraded products functionalities, installing and planning upgrade. CBM providers need to continuously validate the customer requirements and identify upgrade opportunities throughout the product life cycle.	Slow down loop Close loop	• Chat bots or other virtual assistants using NLP to foster co-creation and multilateral communication in B2B/ B2C setting • Sentiment analysis algorithms and predictions to anticipate personalized customer needs and offer corresponding service

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.

So I think and that I need to put that as disclaimer, I'm more expert on the circular economy, not so much on the AI, but I can explain that the availability and the accessibility of data from materials is crucial in order to work with circularity approach of the materials.
I often don't know what materials are in my products.
So let's say data availability is a huge challenge, and therefore that context.
If AI were to help with data availability, that would be huge progress for Circularity.
This is now speaking for the large consumer.
The products like cars, but if you look at, I mean think about yourself or the end consumer, when you have plastic packaging for instance, how you recycle and that they can be now seen from a German or from EU, European perspective, what do you do with the stuff you throw away?
So you don't know the question would be how I could enable consumers at the end of the life cycle, for instance, to better recycle, so to say or what to do with the materials.

Lena Sophie Thielmann
Yes, that's actually in the perfect transition to the first topic that we wanted to deep dive in today because the availability of data is something that is currently also present in research.
A very recent topic and one possible strategy to overcome this lack of data is actually collaboration between different sectors.
So not only between companies, but only also upstream and downstream of the supply chain with the public and with governmental institutions.
So, the part I'm focusing on is the role of cross-sector collaboration in circular economy and how AI can help the transition to more collaboration.
So to start with the topic, I had a look at the different barriers of cross sector collaboration in circular economy in general.

CP
Mm-hmm.

Lena Sophie Thielmann
Those were 27 barriers that the paper by Luthra found, and those could were able to be broken down to 17 because they found that industry 4.0, of which AI is an integral part and can actually help to overcome 17 of those.
But industry 4.0 is not AI itself, so it's not a synonym for for AI.
And that's why I broke it down to 10 barriers.

CP
Mm-hmm.

Lena Sophie Thielmann
Which AI can actually have an impact on and the idea would be that we now look at those barriers and first of all rank them in their importance for circular economy in general.
So that would be probably your field of expertise.

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

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

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

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

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

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

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

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

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

Misaligned interests, that is, maybe even above #1 because a lot of businesses and business models depend on the linear business models with fast consumption. Think fast fashion for instance. There's very little incentive for repairability. Just try to fix jeans again, it's just impossible.
#7 absence of system standardization and performance management. That’s a huge one where I invite you to look into the catina ex activities that the European or German industry is doing. It's between one and three. Ah, no, it might be even higher to be honest, because it makes it painful and also slow if the different actors don't speak the same language in terms of standards.

#8 Risk management. Put it next to #3. Because here, particularly in the automotive space, the designer wants to introduce more recycled metals for certain parts and then the customer safety aka vehicle safety was always an obstacle there.

And then we have poor demand, acceptance of environmentally superior technologies. That goes on the same level as six and seven because here we need to see that very often only because something is recycled it's not necessarily better for the environment.

#10, inflexible policy and structure. This is a problem next to three and eight. I am thinking about material regulations. A huge obstacle in terms of plastic recycling that cars or even Lego bricks that have been produced 20 years ago due to changed legislation that can't be recycled anymore nowadays. So they need to be burned.

Lena Sophie Thielmann
OK.
Thank you.

CP
OK, now we need to see how we shifted to AI.

Lena Sophie Thielmann
Exactly. So the idea of AI is that first of all, it helps to predict patterns among data and has the opportunity to work with a huge variety of data.
Also it has the opportunity to detect anomalies among data and it can kind of, yeah, through this pattern thinking it can learn among itself in a different in a specific setting.
And through this kind of learning and dealing with data, those use cases such as monitoring and or detecting abnormalities, detecting similarities, those use cases kind of come upon that.

CP
OK.
OK, then let's move them around.

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

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

CP
Good question.

Do we have regulation?

Lena Sophie Thielmann
Not specifically at the moment.

CP
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.

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

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

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

CP
That's a good one.

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

CP
That it's a good primer to put me in the right direction. What I would find very helpful is managing conflicting targets.
I will give you a tangible example. We had that for the application of natural materials. For instance, we replace plastic with natural fibers, which reduces the carbon footprint but increases the water demand and increases the risk of human rights issues in the supply chain. So, whenever you try to make something more sustainable or more circular, you have side effects on other dimensions of sustainability, and if someone or some kind of AI technology were able to rather fast simulate the different impacts that the design decision has, like material choice decision. That would be a huge positive impact of AI on circular product design. So that is one thing. Material choice decisions and summarize and compare the implication different sustainability dimensions.
Then. Which I can imagine, and that was in the in the left one for designing for durability. For instance, when you decide if you must make a material 1 centimeter thick or half a centimeter thick. You half your material usage. If you were able to simulate if that material could sustain certain requirements like, is it durable enough? So, kind of a stress test and sensitivity analysis of a material. So you could simulate a lot around the durability requirements. What would happen if I design the material like this or like that.
So that I think are two examples where AI could immediately help.
Think about car that are designed in some unique place in the world. But countries have different country requirements. It would be great if AI could automatically account for these 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 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 anddoubts 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 exactlyfrom when is a business model circular and at what point did I simply implement recycling legislation?

Monument of the straw over the Capri Sun for example or disposable, cutlery, specifications and in recap for coffee to go is it already a circular business model or is it a substitute for waste?   Although that's what I'm getting at, the regulation is independent of whether companies have other problems over which I don't know.
Of course, the power has to accelerate the transformation, because thecompany all at once has to think of straws for example I don't know - Starbucks what the coffee mug cause in the year ne?
But that would be the answer to too general readiness, which is interesting is the startup environment. WhatI always find interesting, are companies that actually have a foresight?
In Germany, I find Lidl interesting, Lidl why?
Because they have started to develop further in the value chain of plastic bottles, for example, with I think prezero means the disposalcompany, has quite a controversial commercial with Günther Jauch at the beginning or middle of the year to address it?I had the impression that those who had the courage. To think more broadly, if you look at the whole thing now in the automotive industry, there is on the topic of circularity right now, that the HV batteries, i.e. the batteries of electric vehicles, topic, there was a lot of fuss 5 years ago, that has become quite quiet.
And I think so Second Life approaches has none for batteries, none implemented on a large scale, there are always a few pilot projects, but that you say, I'm going to drive my old BWM i3 back to the dealer now and the power out there stationary storage of the not so d.

Lena Maria Pertz
Ok okay, that's interesting. That's not something like that yet, I'd say, if we were to look at the value chain of a circular business model now, I'd like to share a slide very briefly, where that's a little bit. Maybe you can look at it together at the moment.
That's exactly what we've seen before, and for my master's thesis, for my part, I'm looking at thevalue chain and especially looking at the areas that are differentiated from a linear business model. And on the next slide I have the main topics that I could filter out a bit.
Here on the left side I have collected the Circle Business Model components and wanted to ask you if you can take a quick look at it and if you think if I forgot that, so actually essential Circle Business Components, which I may not have yet. I've listed here if you notice something, if you notice something, yes.

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

Lena Maria Pertz
Yes yes, that's actually a little bit of something that I've filtered out a little bit now, that's totally important in the whole research, in that I've done so far that the customer, whether it's B to B or B to C, is always involved, so that the customer always has the option to I'm 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 examplewith 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 coordinationneeds, 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 wouldyou 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 tocome 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. Theusually make the business model difficult because it's so expensive, if AI could be used cleverly, let's say, build up distributioncenters, keep logisticsshort, 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. Ifyou'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 ingood 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 whenit'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 haveyour 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,

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

CP

That could work. Alls the one thing is that I had in training and consulting I had thought more about change. In the case of the customer, it says, there was a Dutch jeans brand that also had a subscription model for jeans.
It would be interesting to see if they would have survived. You have to take a look at recycling Holland jeans.
Unless, of course, you go into the topic of AI advertising, sensitization, customer and take them away from maybe even a topic, ne even honestly really bitter.
Theoretically, the whole AI would have to try exactly the opposite, motivating the customer to consume more or the social media user to consume more instead of consuming responsibly.
Yes, that's a steep hypothesis.
The use of AI reduces the likelihood of circularbusiness models by 40%. Yes, tell me, it definitely could be very powerful. I'm in direct contact with customers and communication and now have chatbots.
Here, where, which is interesting during customer communication, when you get the direct customer feedback much, much faster to where it makes sense, i.e. either to the developer, just where it should go, in order to have an impact for CE, i.e. for such a business model. So speed, would be my point here.

Lena Maria Pertz

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

CP

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

Lena Maria Pertz

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

CP

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

Lena Maria Pertz

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

CP

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

Lena Maria Pertz

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

Lena Sophie Thielmann

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

Annelie Sophie Steinbrenner

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

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

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

MH

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

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

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

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

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

MH

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

Lena Maria Pertz

For what reasons exactly is remanufacturing usually not taken into account?

MH

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

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.

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

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

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

Lena Sophie Thielmann
Exactly.

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

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

MH
It's a difficult question because, of course, it's often about what questions I ask and then that's a completely different discussion.
The topic of AI is also a completely separate, stand-alone issue.
Today, companies often go in and say: we collect all the data and then we simply ask what 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 thegruenepunkt 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.

Lena Sophie Thielmann
Yes.

MH
That's why regulation is a huge enabler in this area. But it's definitely creating big problems for a lot of companies at the moment, because there's just so much at the moment.

Lena Sophie Thielmann
Yes, that's right okay and then at point 6 there was actually already a certain similarity to point 3, which means the importance is definitely there.

MH
Exactly.

Lena Sophie Thielmann
That's a huge problem, especially in terms of collaboration, that the goals can't currently be coordinated, right?

MH
The goals cannot be aligned and of course there are also other goals. However, this doesn't just have to do with the industry, but also with the type of company, for example. If I am a listed company, I have different objectives than if I am a family business or a start-up. Accordingly, it is very often difficult to reconcile these objectives. But I don't think AI can really help here. It's a long-standing problem between start-ups and large companies and AI hasn't really helped yet.

Lack of standardization is a problem because the data flows between systems are not given. Companies such as SAP and Microsoft are currently working very hard on this. Incorporating topics such as Co 2 and other Impex into their systems is definitely a problem where AI could then also function as a translator.

The next point is risk management. I wouldn't see this as such a big problem, to be honest.

Lena Sophie Thielmann
On the grounds, so to speak, that it's standardized these days, right?

MH
Of course, it depends on what we mean by risk management. Risk management approaches are of course very different, depending on the company. What we often see is that one company says resource scarcity or resource availability will be a huge problem for us in the future. The other company says no, I can deal with that. Schüco, for example, told us that 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

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

Annelie Sophie Steinbrenner

Yes, ok, that's I think probably the biggest limitation that we've already noticed in our research, that there is of course an incredible amount in this area and you can't look at everything, as you said, but everything somehow builds on each other, but it's very good that you said that again.
I think everything is clear from my side, I think Lena's and Lena's too. Perfect, then thank you very, very, very much.

MH

Yes, that's exactly what I wanted to offer, so if you have any questions or other topics, we can talk again. It's a very exciting topic and I really enjoy talking about it and am of course very curious to see what you come up with.
So when you've finished, I'd love to see how you bring it all together afterwards and what your perspectives are on it.
Great, then thank you very much and have a nice weekend.

Lena Maria Pertz

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 theslides 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 i?
Andthe second question would be?
Let's talk about the circulating business models or secular business mode in the propersense.
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.

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 up 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 learninging 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.
Th e I wanted toask 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 circualrity.
So one point I would rephrase, which is the third point in general Enviornmental 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

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

Lena Maria Pertz
Exactly, okay, yes, yes.

DK
Because what I mean by that is when we want to improve performance in something or at least maintain it. We have to measure it, when we measure something, we have to make it more or less addressee-oriented, and so on and so forth.
And if we have all the information, the data, we now have infinite or many possibilities, the advantages, i.e. in the economic sense as well as in terms of the environment,form advantages e letters, for example through advanced analytics or now the term that has already been coined, predictive maintenance is a very big topic now in industry and actually everywhere.

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

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

Lena Maria Pertz
Always similar yes, I have also seen that it is used relatively often manufacturing, i.e. 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 issomething 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 atmost 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 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 predicative 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?

DK

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

Lena Maria Pertz

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

Lena Sophie Thielmann

First of all, thank you very much for taking the time to talk to us.

DK

Yes, of course, I hope I can be helpful.

Lena Sophie Thielmann

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

DK
Hm.

Lena Sophie Thielmann
I thought about how AI can support this and came across different barriers in my research and broke them down to 10 barriers where AI has points of contact through existing research.
My idea now would be to simply go through the barriers and gather your opinion on them. On the one hand, what is their importance for the circular economy itself and what possibilities does AI have to help overcome them, also in connection with your experiences? And then the aim would be for us to position them together on this matrix.

DK
Okay.

Lena Sophie Thielmann
The temporal dynamics of technologies this simply means that the various cooperation partners have different IT systems in the currently existing status quo and that the development behind these IT systems is also different. So I would be interested to know what your opinion is in relation to the circular economy and AI.

DK
So the aim is to place them in the matrix, right?

Lena Sophie Thielmann
Exactly, yes.

DK
So I would rate the immediate importance for the circular economy as very high, the highest there is. Because at first glance, the topic seems rather trivial, but in reality there really are huge differences between companies. And you really always need a common IT infrastructure as a basis for cooperation. In fact, most companies today don't even have their own infrastructure, which means that they really do write to each other in Word files, or work with Excel or completely different systems. There definitely needs to be an alignment.

Yes, and I think that's a big obstacle because, for example, if you're a bit more advanced now and work with life cycle assessments in your company. These are developed in a specific format. And if you send that, I can't read it in at all because I'm not familiar with such systems.
So I would rate that very highly and the chance of AI acceleration is rather low in the short term, but in the long term it's medium to high.

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

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

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

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

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

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

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.

Lena Sophie Thielmann
Okay, I see.

DK
At least that's my opinion.
I would be against AI doing anything.

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

Annelie Sophie Steinbrenner
Thank you very much Lena. I'm also very happy to be able to interview you today. I'm now going straight into the topic of design. I've also prepared a few slides. Perhaps I'll start by presenting what I had in mind. My research focuses on whether AI can improve or accelerate the design of circular products. What I have found so far is that there are 8 different design approaches that lead to a more circular economy. Either you design for longer use or you design for extended use or you design for recovery.
Starting here, I wanted to ask if this all makes sense to you? Or should I go into more detail here?

DK
No, well, I already know that.

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

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

Annelie Sophie Steinbrenner
To be honest, no.

DK
Because that might be the basic term that might be very important for this topic.
Can I briefly share my screen?

Annelie Sophie Steinbrenner
Yes logically. Just a moment.

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

Lena Maria Pertz
Exactly, yes.

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

Lena Maria Pertz
Ys. That's special. Well, thank you very much again.

Lena Sophe Thielmann
Thank you very much.

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

Annelie Sophie Steinbrenner
Thank you ciao.

Lena Maria Pertz
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.

TE
Yes.

Lena Sophie Thielmann
So the first point, the dynamics of technology, means that today, in the status quo, companies and sectors in particular have different IT systems, but the development behind them is also completely different. Should I go through all the barriers once? Which do you prefer?

TE
Maybe you can go through them all and then I can tell you what I see as barriers.

Lena Sophie Thielmann
Yes, we can do that too. The second one is different operational and management practices. This simply means that individual goals are set that restrict cooperation.
Point 3 is that stakeholder monitoring is different for individual companies in different contexts and sectors.

TE
What does that mean? What do you mean by stakeholder monitoring?

Lena Sophie Thielmann
That different KPIs are set for companies versus public institutions, for example, because cross-sector collaboration is really intended in every respect. So it's public institutions with public institutions, but also with private companies with an extreme customer focus so that society is included too.

TE
Thanks, Mhm.

Lena Sophie Thielmann
So it's really this whole picture of collaboration as you can envision it and it's just that performance monitoring is completely different for these individual parties.
With point 4, we have the risk of information loss because people are not fully aware of what information do I need to share? How is this handled?

TE
Mhm.

Lena Sophie Thielmann
This also extends a little into the point 5, so to speak, that there is simply a reluctance to 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.

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

Lena Sophie Thielmann
Do you see that as a big risk?

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

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

TE
Yes, absolutely. Point 5 poor disclosure. It's an important point, yes, but I think it's being fixed a lot, now with all the regulations that are coming, no, I don't know if issue 5 can really be solved with IT. So I can see that it's definitely important, yes, but it's not an AI issue.
The interests of individuals are not aligned. I would see it similarly, so it's definitely an issue, but it's not an AI issue.

Lena Sophie Thielmann
Mhm.

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

Lena Sophie Thielmann
Yes.

TE
Point 8: Risk management. I can't say that. For me, it doesn't have that much to do with AI.

Lena Sophie Thielmann
Mhm.

TE
That's a bit abstract for me, I can't really put it into perspective.
What exactly do you mean by low demand for ecological technologies? Is that an issue?

Lena Sophie Thielmann
I've read that developing countries are rushing into the landfill issue, simply because they are building a network with more economically developed countries and simply don't have the money to make major changes right now, so they are using more sustainable technologies in order to be part of a collaboration in the circular economy.

TE
Okay, so then you could even say that's high, but I don't see the AI impact directly.

Lena Sophie Thielmann
Mhm probably more of a communication issue then, right?

TE
Communication topic and also regulations, i.e. laws, regulations and also other incentives such as taxes etc.

Lena Sophie Thielmann
Yes.

TE
Inflexible policy. Yes, that's definitely an issue, so I don't know if you're always looking at it globally, but as I said, a lot is happening in the EU. Many people in Germany would almost say it's radical, yes, it's tough, what's being implemented and all that. But that's a good thing.

Lena Sophie Thielmann
That means that the problem for the circular economy is no longer so great because so much is already happening.

TE
Yes yes, but also not an AI topic exactly.

Lena Sophie Thielmann
Okay.

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

Lena Sophie Thielmann
Yes, that's definitely true.

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

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

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

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

TE
With pleasure.

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

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 dispoed, 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.

Lena Maria Pertz

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

TE

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

Lena Maria Pertz

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

TE

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

Lena Maria Pertz

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

TE

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

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.

I don't know to what extent AI can also do problem solving in this way. Along the lines of, what are the drivers now? What are route causes for wear and tear or failure? AI can certainly provide support here.
I imagine it along the lines of - not like a physical test, where someone always presses something on the chair, at Ikea - but everything is played through in 10,000 cases with different constellations, calculated and insights are then determined from this. What are the most important design factors for durability, etc.? AI can certainly do a lot here.

Annelie Sophie Steinbrenner
Yes, I understand that.

TE
And something similar, I would have said now, you can also do in 3, Maintainability. So that's all a topic for me: playing through product usage, repair cases, etc. So I think 2, 3 and 4 are very similar.
And upgrading. I don't know how Ai can help with that. For me, that's more a question of product strategy, isn't it? I'm having a bit of a hard time with that. I don't know. I don't know much about that either, to be honest.

Annelie Sophie Steinbrenner
No problem at all.

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

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

TE
I think that's a bit similar to 2, physical durability. It's a complex topic. What outputs do you get out of it afterwards? So assuming any steel grids or frames or whatever? How do they have to be configured, designed, so that there is a market for them afterwards or so that they can be reused in a meaningful way? And what is the best way to install them so that you can get them out again with reasonable effort?
I'm guessing that you can simulate something like this using digital twin.
But I'm a bit conjectural about that. I'm generally not that into design topics.

Annelie Sophie Steinbrenner

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

TE
Exactly.

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

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

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

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

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

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

Annelie Sophie Steinbrenner

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

TE

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

Annelie Sophie Steinbrenner

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

TE

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

Annelie Sophie Steinbrenner

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

TE

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

Annelie Sophie Steinbrenner

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

TE

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

Annelie Sophie Steinbrenner

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

TE

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

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

TE
No, nothing that comes to mind immediately.

Annelie Sophie Steinbrenner
Okay, all right. Great. Then that's it from my side and then I would like to thank you for your time. I think we can definitely take away many, many valuable insights from this conversation and incorporate them into our master's thesis.
Now I would like to hand over to Lena Thielmann again and wish you a good rest of your day.

TE
All right, thank you.

Lena Sophie Thielmann
Yes, from my side as well. Thank you very much. Really. You saved us a bit with that and definitely helped a lot.
I don't know what your impression of our research might be, i.e. whether you think we're actually quite well positioned in terms of the circular economy? Or have you missed something or is there something that we may have completely overlooked?

TE
Yes, I think you have good approaches and I think you've also seen that because sometimes everything goes a bit haywire with AI and I think many people use AI and don't really know what it actually is.
And you could tell that you thought about what AI can do in particular compared to perhaps normal modeling optimization.

Lena Sophie Thielmann
Yes. People talk a lot about AI, read a lot more about it, and you can get lost super quickly and that was also the challenge for us, so to speak. To break the topic down to the essentials.
That's why we're pleased that it seems to have worked.
We're very excited to see how the evaluation turns out in the end, but thank you very much and we'll definitely see you soon.

TE
All right, great, then take care.

Lena Sophie Thielmann
Thank you ciao.

Lena Maria Pertz

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

TE

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

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

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

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

Lena Sophie Thielmann
Because it is kind of an automized process or why?

PdH
Why lower?

Lena Sophie Thielmann
Yes.

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

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

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

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

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

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

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

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

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

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

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

Lena Sophie Thielmann
And for circular economy itself, the risk management approaches. How do you see that combination?

PdH
So a #8 you mean?

Lena Sophie Thielmann
Yeah.

PdH
I find it hard to can you give me an example of a risk that you that you have in mind here?

Lena Sophie Thielmann
For example with the new regulations coming into place, you have to have like a certain know amount of recycled materials in your product. But you don‘t have the suppliers today, so that's actually a risk that you have to approach when engaging in circularity activities and the companies do perceive those risks differently becauseif you have a tangible product, you perceive it differently than a service company. But that's the role of the barrier I had in mind when it comes to circular economy.

PdH
Yeah. Reminds me of a risk that sometimes suppliers of waste materials for them it's not so much, you know, an issue if it's a bit late. But for manufacturers that are using their base materials as raw material for their own manufacturing they perceive it as a much more critical that the availability of such materials takes place in time. So yeah, I think it's pretty important. I would move it up to.

Lena Sophie Thielmann
OK, great. And then we have the 9th point, which is the lack of demand and acceptance for environmentally superior technologies. For example, in developing countries, because today there are mainly used as landfill and focus on that as an economic activity for them and are not really interested in investing in like really environmentally superior technologies, what do you think about that?

PdH
Yeah, I think it is important on the vertical axis. Uh, so pretty high, but not very high. I would put it slightly below 8 or perhaps move eight a little bit higher, but anyway. And also horizontally I think to me that is again, there are multiple factors that drive that demand, one of them is perhaps a lack of information or knowledge about such technologies, there AI could help, but I think more important drivers are, you know, what is sort of the incentives for companies to use such technology. I think that's a far more important factor than the availability of information. Ohh yeah, I wouldn't put it too far to the right.

Lena Sophie Thielmann

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

PdH
What again is C-SC and CSCM?

Lena Sophie Thielmann
Cross sector collaboration and circular supply chain management.

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

Lena Sophie Thielmann
Yeah, of course.
Very, very, valuable points. And then thank you so much.
Then I'm already done with my questions and I would hand over to Lena.

PdH
Yeah.

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

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

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

Lena Maria Pertz
OK, so basically automated a little bit.

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

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

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

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

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

PdH
Umm yeah, that makes sense. I I think I would agree with those use cases.
Perhaps at another one, and that is the for the company that leases the equipment or products to enhance their demand forecasting. All all also at local levels, so they can optimize the the distribution of the of the of the equipment they want to lease to consumers or other actors.
So yeah, that would be another use case, OK.

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

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

Lena Maria Pertz
Umm, correct. Yeah.

PdH
Yeah, yeah, that makes it that.
It makes a lot of sense, and with AI you can improve the uh, the personalization.
Uh, and, you know, increase the quality of the matching.
Yeah, that's all that.

Lena Maria Pertz
Perfect. That's amazing. I think we also ready for my part and we are in time I guess.
Thank you so much.

PdH
You're welcome. But I also had one other English case that I wanted to mention that which is maybe. I'm not sure it's relevant for your piece of the work, but.
And it's it's still also experimental, but it really it relates to modularization or componentization. I think it's the word of products and you know The thing is that there is also a trade off if you if you make your components bigger and more integrated, they're easier to swap and easier to a major because it's, you know, you just have an integrated

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

Lena Maria Pertz
OK, I think this is actually a bit more of the topic of Annelie, which is the perfect transition basically. Ohh excellent. So she already has the use case.
But yeah, thank you so much for the for the last 15 minutes, it was very helpful.
Have a nice day.

PdH
You too.
Thank you. Bye.

Lena Maria Pertz
Thanks.
Bye, bye.

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

PdH
Yeah, it’s better to walk me through.

Annelie Sophie Steinbrenner
All right. So, umm what I did is I turned to literature and what I found is a model by Den Hollander, who came up with eight different design strategies all belonging to 3 major goals. The first goal is to design for long use. The second goal is to extend the use of a product and the third one is to recover.
I think the strategies for the long use are easily understandable. You can design either for emotional durability or for physical durability. Then for the second goal of extended use, you can either design for easy maintenance, easy repair, or upgradability. For the last goal of product recovery, you can design for recontextualization, refurbishment or remanufacturing.
So my question would be, how can AI help to realize these design strategies? So, where's the role of AI and where does it come into play?

PdH

So I think as was mentioned by Lena number 2.
The use case that I just mentioned I think applies to what you mentioned in one of those design strategies. I'm not entirely sure which one it relates to, but I guess it's about this component optimization as I call it. Umm which is, you know, good for use. So that people keep the product right. So they like it and they keep it. At the same time it balances that with the extent to which the product can be remanufactured or taken apart and used for other purposes.
Then another use case or use of AI in this context, for instance, could be in… Well, what I found fascinating was the emotion. What did you call it? Emotional attractiveness of the product or something like that.

Annelie Sophie Steinbrenner

Emotional durability, yes.

PdH

Yeah, yeah, yeah. So, here, perhaps AI together with other technologies could play a role in the sense that depending on the product, you could perhaps use AI to offer more, let's say personalization options like changing the color or changing the way the product looks or feels.
And then perhaps by using AI you can make the product more flexible without replacing it. So people can change the looks of the product. If they are bored with the former version they can keep it more attractive for themselves. Uh, so that I think is one use case that came to mind.

Annelie Sophie Steinbrenner

Yeah, that sounds good already. So maybe it makes sense to go one after the other through the different design phases.
So, what I already found is that AI can definitely have a role in ideation and concept development. So, for graphic inspirations, for instance. Do you see the role of how this can also be applied, not for design in general, but specifically for circular design?

PdH

Yeah, let me think about it. Well, I think that in an ideal world your new product ideation would already take the future circular use of its components into account, right? So that should be ideally a design criterion from day one. So, I guess AI could help, perhaps to say OK, here's a new idea. How could that be used once this product is end of life? How could we use it for other purposes. So that I think could be a nice example to have this sort of circular by design principle already in your ideation, if that makes sense.

Annelie Sophie Steinbrenner

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.

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

Annelie Sophie Steinbrenner
I’ve heard of that. Yes, yes, very interesting.

PdH
So that would be an example.

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

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

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

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

Annelie Sophie Steinbrenner
Well, definitely, I think I can take a lot of that.
I think we're already over the time.

PdH
Alright, yeah.

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

PdH
My pleasure.

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

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

Annelie Sophie Steinbrenner
Yes, that's perfectly fine.

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

Annelie Sophie Steinbrenner
Yes, yes, of course, of course.
So thank you once again and have a nice day.

PdH
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

Mhm.
So when we talk about IT, the blockchain immediately comes to mind when I think of the circular economy.
And I think the IT level between the various companies is as low as possible, because everyone is at a very low level. But as such, for the circular economy, I would put it on the first line from the top, i.e. medium importance. Exactly.

Lena Sophie Thielmann
Mhm and AI has impact possibilities, as you just said with blockchain?

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

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

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

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

HK
I would. Also add to #2.

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

HK

It is also extremely important for the circular economy because the loss of information shouldn't actually happen, you always have to know, for example, about the content of the material data passports or similar, which now also has to do with the Eco Design Directive, for example. That has to be a given, so it's very important for the circular economy. And I 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 relevant.

Lena Sophie Thielmann

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

HK

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

Lena Sophie Thielmann

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

HK

Mhm.

Lena Sophie Thielmann

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

HK

Oh, I would even put that at the top of the list for circular economy, because that's a major problem. Therefore, even above the 4 that we have already placed at the top, because I think a major problem is that I don't think people have a consistent picture. It's not without reason that Mr. Kirchherr, a McKinsey consultant or partner for circular economy, has published a paper on the conglomeration of hundredfourty definitions of a circular economy or 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.

Lena Sophie Thielmann

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

HK

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

Lena Sophie Thielmann

Yes.

HK

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

Lena Sophie Thielmann

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

HK

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

Lena Sophie Thielmann

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

HK

Very good. With pleasure.

Annelie Sophie Steinbrenner

Exactly, so to start right in, my research focus is on product design and specifically can AI improve or accelerate the design of a circular product.
I've just looked at various design frameworks and have now settled on one. This framework here describes 3 goals, namely designing for long use, then in the middle for extended use or even for recovery. And as you can see, there are a different number of design strategies for each of these overarching goals. For long use, for example, you can design for emotional durability and physical durability, for extended use for things like maintenance, repair, upgrading and for reclamation for recontextualization, refurbishment and reprocessing.
First of all, I would like to ask how can AI help to realize the design strategies or even the design goals?

HK

Mhm just loose now? What comes to my mind?
There are companies, I think Oerlikon or other 3D printing companies, for example, that can build extremely complex shapes using lasers or other metal-forming 3D principles and I think there is potential there, for example. What if I look at this now...
Well, I think the recovery of materials. With cars, for example, you have the problem that disassembly is not guaranteed because clips, i.e. plastic clips, are used and you can't separate them from each other, or at least you can't separate them non-destructively. And I think AI could get a lot out of that in product design, i.e. in the design of how the molds are created.
And now. Let me just go through the numbers of the design strategies from left to right.
I think design for emotional durability is also high. If I understand correctly, emotional durability is that I buy the white cup and I think it's great today and I'll still think it's great in 10 years' time, right?

Annelie Sophie Steinbrenner

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

HK

Ok, then I also see there that AI can help to realize a design strategy, because I think the data evaluation alone. If you do market research and collect data, i.e. customer interests, how long products stay with people, how they are passed on and so on, then I think AI can definitely help.
Design for physical durability. So it's extremely important that products last longer. But I think AI could perhaps also help here in terms of weighing up how long a product needs to last. In other words, life cycle assessment.
For example, at the moment people often make fallacious conclusions. Something like, I'd rather buy an aluminum bottle, I'll have it for 10 years and therefore I won't buy any more plastic bottles. But what if the plastic was a monomer and extremely easy to recycle?

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

Annelie Sophie Steinbrenner
Mmh.

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

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

HK
Mhm yes, okay, so I was just on the fence about maintenance, but maintenance, I'm back to that. If you look at predictive maintenance now, it's a super important topic.
If you look at production and the production machines, predictive maintenance is of course extremely important in the sense that the products that come out are of course good, but also that you don't have any downtime in the factory.
But also later on. I mean, if you sell a washing machine or a dishwasher or a refrigerator or something. For example, my dishwasher broke down 3 weeks ago and if he had told me a week before that "Hey, next week it's very likely that the heat pump will break down, just ask the repairs department."
In this respect, I think predictive maintenance and AI, it's a match.

Annelie Sophie Steinbrenner
Mhm.

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

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

HK
I think design for upgrades makes sense from the perspective of a company, for a company that also sells the products in turn.
So, I've described design for maintenance from the perspective of the end user, the things for upgrading are also partly for end customers.
But I think for the business model of a company... When do I have to approach my customers so that I can tell them again "The upgrade is" and to take that into account in the design would be mega cool. But I don't know if that would work.
But I think AI for upgradability could also help in product development, data processing or market research.

Annelie Sophie Steinbrenner
Mhm.

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

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

HK
Ok this recontextualization I could also imagine that AI helps in the evaluation of what to upgrade or what to upcycle, what to downcycle or now in the decision-making process, whether this is the case at all. Whether I now say it will be taken again directly in another case. Whether I should ultimately remanufacture or recycle, etc.?
I think AI could certainly provide support in the decision-making process.
Design for refurbishment measures was refurbishment?
I think that's another consequence of 6, recontextualization?
As I've already said, AI can also help with the decision as to whether it should be refurbished or not. I see potential there.
And design for remanufacturing. There too. Although I'm now most critical of remanufacturing. Critical of the product that is returned to the customer, because in my mind remanufacturing is often associated with the warranty, because it really is returned to the customer in its original condition.
For example, if we have an engine that is remanufactured, then the pistons are milled out again and so on, and there is a liability involved. I also see potential in the testing of such products, for example, and in the decision beforehand.

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

HK
Mhm.

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

HK
Mhm on the point 5, upgrading I wouldn't say predictive maintenance but predictive upgradablity. Or predictive potential.
Annelie Sophie Steinbrenner
Yes, yes, okay understood.
I would like to ask you again about monitoring. Do you think AI could also help with monitoring, i.e. tracability, also in relation to a digital twin, for example, to find out when all these things like maintenance, remanufacturing or something like that need to be addressed?

HK
Yes, I think it very much depends on what kind of products we're talking about.
If we're talking about machines that have a high throughput or manufacturing machines in general. I can totally see that. A digital twin also makes a lot of sense for other reasons.
But if you're talking about design for circularity. Let me give you an example. An office desk doesn't need a digital twin or a Shadow.
I think it makes sense for expensive products with a high degree of utilization. On an industrial level. I mean, you could somehow buy an extremely expensive suitcase, an extremely expensive handbag, but you don't need a digital twin for that. You don't need the real-time analysis. But with other products, yes.

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

HK
Great, I'm glad.

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

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

HK

Perfect, so a take back system would be closing the loop, wouldn't it?

Okay, so with the first one I would now validate the two use cases from my point of view, makes a lot of sense, but I would like to think briefly about whether I can contribute more to it afterwards. I think it's a good point with route optimization, but I think it's also about finding where are my route optimization? So optimization is, have my locations and how do I optimize the route in between? For me, the question is, where do I put take-back locations, for example? So, in the end, exactly the same decision, why is a factory built for the car manufacturer and built there, but not built here? Built and there it is, I think the same thing, so why such a site assessment for them?

Would you use the Take Back System for the local Tec System?

I might see that in the step before.

Lena Maria Pertz

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

HK

Yes, exactly, so that certainly makes existing things to take, but I think there is also potential to create new spaces and build new logistics centers or something.

Point 2 they have is about maintainance, repairs and upgrades and maximum user friendliness.

Lena Maria Pertz

In an interview, I have not yet been able to familiarize myself with the fact that you could theoretically already use chatbots or virtual systems, because you can, so to speak, when these predictive maintenance analyses are run, from the vendor, I say, who then somehow has to inform the customer hey, we somehow have something detected, the machine will most likely fail in the next 2 weeks.

We come by and then do service so that you could theoretically integrate the chatbots for these ready-made processes.

HK

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 - theage distribution, for example now in Germany, then I think the majority are simply not interested in chatots. 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.

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

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

Lena Maria Pertz
Okay, yes, I'll write it down.

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

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

HK
Whereby now means that my point that I made at the beginning was really more from the service point of view.
Not product in have nen company so like Check 24 really that the look of exactly yes I would have now I would have said now.

Lena Maria Pertz
Ok, comparison portal, so to speak.

HK
Mhm Sharing platforms customers
Yes, I would now also confirm, I also see.

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

HK

let me think about it for a moment, I had something in mind, but I think I already had that earlier. Once called. I think what the simplest guarantee is for Uwe yes so now, now it's a mix of 2 topics, but this influence cola riti in the sense of circular business model could also be just that you keep the product designs. Created by an artificial intelligence. So the one, for example, so I can just get it from so I know it from is a rocket engine. Drive that was this use case, what I think with friend, me from Oerlikon, they have there. It's not Oerlikon, I might try to send you that slower, but they don't do anything else than you give ne input, for example the cup and the saws, he only gets this button but does it?

Organically have it in organic form and if you can do that, you can also say to yourself ne Hey. The others, the topics that we mentioned earlier, and I think this could also be done as a software service business model, so if you now have a CAD program to design or develop products on the computer, like autocad Inventor for example.

I would also see that as a bit of a hotel, that you simply accommodate developers and offer them, so to speak, circular bids that they can simply automatically incorporate into the product designs.

Lena Maria Pertz

Okay, so it's a bit of a marketplace for designers?

HK

Exactly.

Lena Maria Pertz

That would mean that you can run different automation processes for those of their provider and then, so to speak, through their provider, which then probably even drag subscription.

HK

Yes, that would be perfectly clear.

Lena Maria Pertz

Yes, okay nice perfect that sounds good yes I think, then we are finished from my side for the time being, thank you very much for your time and your inputs.

HK

Absolutely.