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

BUILDING BLOCK A: CIRCULAR PRODUCT DESIGN

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This paper explores the intersection of artificial intelligence (AI), circular economy (CE) and product design. Emphasizing AI's transformative role in circular product design (CPD), the research identifies key AI applications – pattern recognition, prediction, and generative modeling – across design phases. Through in-depth case studies and expert interviews, a comprehensive framework is developed, illustrating AI's impact on product integrity, measured in longevity, extended use, and recovery. The study contributes theoretical insights by bridging CE, CPD, and AI literature, offering a nuanced understanding of industry-specific variations. Practical implications stress the necessity to enhance designers' and managers' AI capabilities for streamlined, sustainable product development.

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

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1 Introduction

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

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

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

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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

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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 MacArthur 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

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(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

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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*

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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

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

2.2 Artificial Intelligence

2.2.1 Definition and Evolution of Artificial Intelligence

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

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

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

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

2.2.2 Benefits

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

2.2.3 Challenges

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

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

2.3 Artificial Intelligence in the Circular Economy

2.3.1 Increasing Role of Artificial Intelligence in the Circular Economy

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

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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

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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

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

3 Research Outline

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

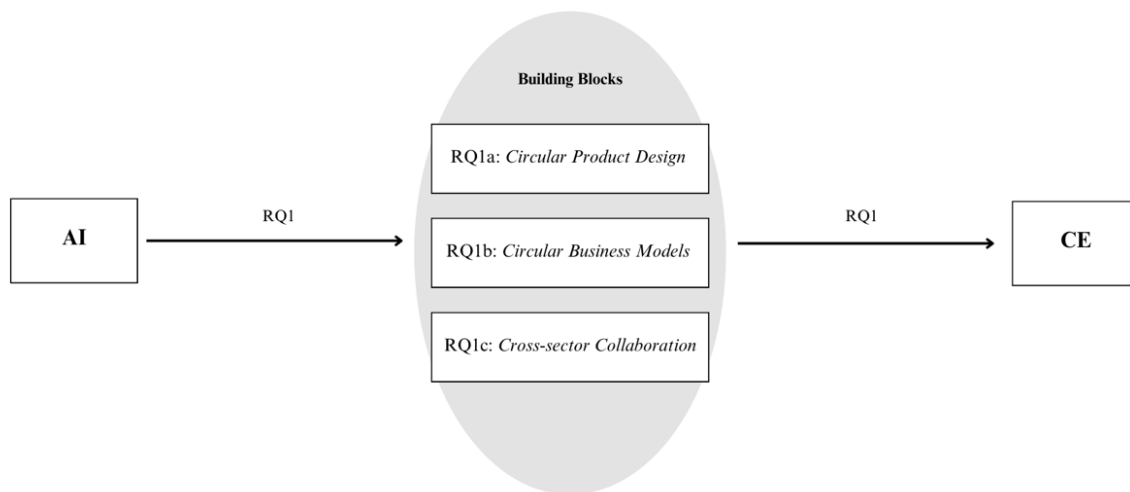


Figure 1. Comprehensive research model (Source: Own illustration)

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

4 Methodology

4.1 Research Design

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

4.2 Participants

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

4.3 Data Collection

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

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

4.4 Data Analysis

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

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

5.1 Introduction

The European Commission emphasizes that any product has an impact on the environment throughout its life cycle - from the use of raw materials to design, production, packaging, transport, disposal, and recycling (European Commission n.d.). Remarkably, over 80% of this impact is predetermined during the design phase, underscoring the importance of integrating circular considerations into product design (Ellen MacArthur Foundation 2020). Early attention to circularity is crucial because once product specifications are set to a certain product design, making substantial adaptations becomes challenging (Bocken et al. 2014; Saidani et al. 2019). This implies the need for more innovative design solutions at an early stage to ensure prolonged product life cycles (Berg et al. 2020). The Ellen MacArthur Foundation (2019) highlights AI as a technology capable of effectively addressing circularity challenges during product development and design.

The current literature on AI-enabled circular product design (CPD) is limited, primarily discussing the potential of AI to accelerate the design process (Ellen MacArthur Foundation 2019). However, there is a lack of guidance on how and where to integrate specific AI applications in the circular design process. This study aims to address this gap by identifying key areas where AI applications can add substantial value to the circularity of tangible products. This is explored through research question RQ1a:

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

To address this research question, the subsequent sections are organized as follows. First, an extensive review of the existing literature is conducted, covering the principles of CPD, the concept of product integrity, and the influence of AI within this domain. Second, this paper delves into the research methodology. Third, a comprehensive presentation of findings shows

insights gained from both case studies and expert interviews. Next, the study introduces a novel framework derived from the findings, which highlights the impact of AI applications on CPD. Fifth, theoretical and practical implications are outlined. Ultimately, the study discusses research limitations and recommends avenues for future research.

5.2 Literature Review

5.2.1 Circular Product Design

Product design (PD) is the process of creating and developing objects or services to satisfy market demands. It involves various disciplines such as industrial design (aesthetics, ergonomics, user interfaces, etc.) and engineering (mechanical, technical, software, etc.), with the aim of producing products that are both visually appealing and functional (Ulrich and Eppinger 2004). Thereby, the key design phases, as outlined by Quan et al. (2023), include user research, idea generation, product display and evaluation. Traditionally, PD followed the tenets of a linear economy, characterized by the take-make-dispose model (Andrews 2015). After the Great Depression, the introduction of planned obsolescence – creating products that quickly become obsolete – served to stimulate the market and enhance corporate profits (Packard 1960). Nevertheless, the undeniable ecological shortcomings of this method have spurred the emergence of novel design concepts aimed at reducing environmental impact, amongst others CPD (Moreno et al. 2016; Ceschin and Gaziulusoy 2016). In contrast to traditional linear product design (LPD), which focuses on generating economic value through multiple sales of goods or services, CPD prioritizes one-time sales by designing for increased product functionality and longevity (Vanegas et al. 2018). As defined by the Ellen MacArthur Foundation (2019) CPD aims to “keep products, components and materials at their highest utility and value at all times” (12). CPD seeks to optimize material use and minimize waste through designing for closing and slowing the resource loop (Vanegas et al. 2018; Bocken et al. 2016). While design to slow down the resource cycle aims to prolong the lifetime of a

product (through design for attachment and trust, reliability and durability, ease of maintenance and repair, upgradability and adaptability, standardization and compatibility, and disassembly and reassembly), design to close the resource cycle aims to recycle materials into their original form (through design for a technological cycle, a biological cycle, and design for dis- and reassembly) (Bocken et al. 2016) (Appendix A1). By focusing on product durability, usability, and recovery, CPD strategies aim to maximize economic and environmental value (Van den Berg and Bakker 2015).

5.2.2 Design Strategies for Preserving Product Integrity

According to Den Hollander (2018), CPD includes two design concepts: design for preserving product integrity at the product or component level and design for recycling at the material level. Defined by Den Hollander (2018) product integrity entails designing the product to retain a state as close to its origin as possible, preventing premature obsolescence. Den Hollander (2018) advocates for design strategies that place importance on prioritizing use, and reuse, in other words product integrity, over recycling. The rationale underlying this approach is grounded in the belief that promoting continuous functionality and utilization contributes significantly to a product's overall sustainability. In contrast, recycling, with its inevitable processes of dismantling and reprocessing, is seen as introducing disruptions to the product's integrity, which should always be a designer's primary goal (Den Hollander, 2018). Hence, Den Hollander (2018) evaluates product circularity based on product integrity alone. He names three circular design strategies to preserve product integrity: long use, extended use, and recovery. Each of these design strategies are further accompanied by a total of eight sub-strategies, as shown in Table A1 and defined in Appendix A2.

Design Aim	Preserving Product Integrity		
	Long Use	Extended Use	Recovery
CE Strategies	Design for Emotional Durability	Design for Maintenance	Design for Recontextualization
CE Sub-Strategies	Design for Physical Durability	Design for Repair Design for Upgrading	Design for Refurbishment Design for Remanufacturing

Table A1. Circular design strategies for tangible products. Adapted by Hollander, M.C. Den. 2018. “Design for Managing Obsolescence: A Design Methodology for Preserving Product Integrity in a Circular Economy.” *Delft University of Technology*, June

Design for long use refers to slowing down the flow of resources by increasing the lifespan of a product. Consequently, products must be durable and reliable in use. This involves actions aimed at enhancing both emotional and physical durability. Emotional durability refers to creating products that foster lasting connections with users, ensuring that products remain relevant and cherished over time. Physical durability involves constructing products with robust materials and structures to withstand wear and tear. *Design for extended use* includes all measures taken during a product’s life to extend its useful phase. Designing for maintenance involves creating products with components that can be readily serviced, ensuring longevity. A focus on repairability empowers users to repair or exchange broken parts, further extending the product’s life. Upgradability is about the modular design of products that allow the user to upgrade certain components instead of replacing the entire product. These strategies contribute to a more resource-efficient approach by maximizing the utility of each product. *Design for recovery* entails planning for the end of a product's life. Recontextualization explores alternative uses for products at the end of their lives if they can no longer serve their original purpose. Refurbishment focuses on restoring a product to a satisfactory working condition, which may be inferior to the original specification but extends its usability. Remanufacturing, encompassing the systematic disassembly of obsolete products into components, testing, and selecting eligible components, and then reintegrating these

components to construct a new product with similar specifications. By incorporating these design actions, products are endowed with multiple lifecycles. These circular design strategies serve as a robust guide for designers, ensuring that products not only withstand the test of time but also retain their functionality and value throughout their lifecycle, aligning with the principles of the circular economy (Den Hollander 2018).

5.2.3 Artificial Intelligence in Circular Product Design: Current Landscape

In recent years, a novel research area has emerged, focusing on the convergence of AI, CE, and product design. Despite the limited number of studies in this field, existing studies highlight the potential of AI in CPD (Ellen MacArthur Foundation 2019; Roberts et al. 2022). AI facilitates CPD decisions by suggesting eco-friendly designs or adapting existing ones based on environmental considerations (Ellen MacArthur Foundation 2019). For instance, AI enhances the understanding of components suitable for the biological versus the technical cycle, thereby improving component separation and recycling potential (Roberts et al. 2022) (Appendix 1). Drawing on studies like Acerbi et al. (2021) and Gailhofer et al. (2021), AI aids in establishing design parameters that prioritize local or recycled materials, reducing resource extraction and transportation-related emissions. Moreover, AI contributes to the development of sustainable materials, replacing harmful chemicals and improving product durability (Ellen MacArthur Foundation 2019). Furthermore, algorithms are capable of rapidly generating diverse design alternatives, optimizing for multiple circular variables (Ghoreishi and Happonen 2020). Lastly, AI can analyze feedback from currently used products, extracting best practices for new designs (Ellen MacArthur Foundation 2019). Despite these AI opportunities to support the design process, challenges lie in successfully integrating specific AI applications in CPD phases.

5.2.4 Development of Research Gap

While the literature acknowledges AI's potential in CPD, a critical gap exists in providing clear guidance on how AI can strategically enhance the distinct phases of circular product design. Moreover, there is a shortage of studies that connect theoretical concepts with practical case applications. Hence, successfully integrating AI into CPD demands a detailed framework to guide companies in the transformative journey towards prolonged use, extended product lifespan, and efficient product recovery. To address this knowledge gap, the study aims to identify specific AI applications and assess their value in enhancing the design process in the context of real company use cases and practical know-how. Furthermore, this research seeks to develop a framework that connects AI applications and circular design strategies and serves as a guide for the transition to more product integrity.

5.3 Methodology

5.3.1 Research Design

To answer the research question of how AI can be integrated in the design process to impact circular design, a step-by-step research process was undertaken, which consisted of three parts: (1) an in-depth analysis of three case studies, (2) expert interviews, and (3) a combination of the results (Appendix A3). First, case studies including semi-structured interviews with design experts of three manufacturing companies were conducted to understand the circular design strategies and AI applications used in real life. The reason for conducting case studies lies in the current phenomenon that AI in CPD is still predominantly theoretical and insufficiently considered in its real-world context (Aguiar et al 2021). Furthermore, according to Yin (1984), case studies are useful for integrating new insights into a current theoretical phenomenon. The study creates knowledge about which circular design strategies companies apply by referring to the CPD strategies mentioned by Den Hollander (2018), as described in section 5.2.2. This research focuses exclusively on design for

preserving product integrity without considering design for recycling, because design for recycling is a well-established concept that has been covered in detail in past literature (Aguir et al 2021; Ghoreishi and Happonen 2020). Furthermore, the study provides insights into how these companies use AI in their product design to achieve circular design strategies. The second phase of the study consisted of conducting semi-structured interviews with AI, CE, or AI-CE experts. Section 4, titled Methodology, provides detailed information on the collection and analysis of expert interviews. These insights aimed to verify and complement the previously mentioned AI applications supporting CPD. The integration of findings from both case studies and expert interviews in the third phase yields a comprehensive understanding of AI applications and their impact. Ultimately, the study introduces a novel framework outlining the role of AI applications in CPD.

5.3.2 Data Collection for Case Studies

The data collection followed a similar approach to the data collection of the expert interviews in section 4. It involved a careful selection of three case companies based on two key criteria. First, the companies must be actively involved in the development and manufacturing of tangible products to ensure a direct link to the focus of the study, which is product design. Second, the selected companies must have some experience with AI and CE to ensure a foundation of expertise in these focal areas. The three selected companies operate in different industries and are of different ages and sizes, which provides a well-rounded perspective on the application of AI in product design. Interview partners were purposefully selected based on roles within the company and their direct involvement in product design or manufacturing. They were searched for and contacted via LinkedIn. This targeted approach ensured insights from individuals with a comprehensive understanding of the subject matter. All interviewees were anonymized based on the first letters of their first and last name. The interviews were conducted through 30-minute video calls via MS Teams, from November 8 to November 10

in 2023. Mirroring the approach of the expert interviews, interviewees provided consent for recording and transcription prior to the discussion, with MS Teams facilitating this process. While a set of predetermined questions provided a structured approach, most of the questions emerged organically during the discussions. A descriptive summary of the case companies and interviewees from each organization is presented in Appendix A4 and A5, respectively. Data analysis of the case studies followed the exact same approach as the expert interviews, explained in section 4.4.

5.4 Findings

5.4.1 Case Studies

This section outlines findings from three case study interviews. Expert interview transcripts are shown in Appendix E and interviewees are cited based on the first letters of the interviewee's first and last name.

5.4.1.1 Company A

Company A is a young fashion manufacturer that uses AI to create and produce long-lasting zero-waste designs. Its goal is to revolutionize the fashion industry by transforming fabric waste into new apparel products and prevent future waste through automated design patterns.

Circular Design Strategy

Company A focuses on product longevity and zero fabric waste. Its aim is to guarantee a product lifespan of 30 years or more by designing timeless, simple designs combined with the highest quality. Significantly improved physical durability and product resistance to wear and tear is ensured through careful construction, stress testing and double stitching in the design and manufacturing phase, for example. Furthermore, simple, and straight cuts of the designs make repairs and re-stitching easier if seams should unexpectedly open throughout the product's life cycle. Last, by turning left-over fabrics from partner brands into new apparel,

Company A fosters alternative uses for the existing materials that might otherwise go to waste. In essence, Company A's designs are characterized by a high level of long and extended use and the recovery of leftover fabric as defined by Den Hollander (2018).

AI Applications

Company A uses existing data sets comprising previously self-developed designs and synthetically generated designs to train its deep learning model. Based on the training data, the trained model can draw inferences on new data. For instance, the model uses sketch and fabric information to subsequently suggest new, waste-free fabric patterns that auto-adjust across sizes, fabrics, and styles. For example, a design is traditionally created for a standard fabric width of 60 inches. Hence, if a fabric was only 55 inches in width, it would usually be thrown away. In the spirit of zero-waste fashion, Company A, however, uses deep learning algorithms to adapt the pattern design to the new fabric size within seconds. The proposed design patterns follow a zigzag shape with no gaps between the individual fabric parts, so that no waste is left over (Appendix A6). Deep learning algorithms not only enable design adaptation through pattern recognition, but also facilitate the scalability of zero-waste designs by reducing time-consuming, labor-intensive, and resource-intensive manual processes.

5.4.1.2 Company B

Company B is a manufacturer of semiconductors using AI and machine learning in the design process to analyze past chip designs and optimize products for better reliability while reducing costs.

Circular Design Strategies

Company B's circular design approach centers on designing chips for long use while minimizing waste in semiconductor manufacturing. The company prioritizes reliability and error-free production from the initial design, emphasizing the correct-by-construct principle. Company B's primary goal is to avoid repairs and remanufacturing over the course of the

product's life and to ensure that every chip meets strict quality standards in order to avoid product errors and defects in the first place. Based on Den Hollander's (2018) circular design strategies, Company B focuses on long use.

AI Applications

Company B employs a comprehensive set of digital tools to enhance the circularity of its products. Through advanced data analytics, Company B collects and analyzes extensive data on the lifespan of previously sold semiconductors. Based on this data, Company B leverages machine learning to recognize patterns on chip failures and design bottlenecks. Automatic pattern recognition ensures that past errors are encoded and not repeated in new designs. In addition, Company B utilizes AI by performing potential lifecycle simulations of newly designed chips. Through prototyping and testing of new chips in a digital environment, resources are saved that would otherwise be needed in tangible chip design. Utilizing AI and machine learning, design processes that previously required up to a year are shortened to approximately four weeks, resulting in significant time and cost savings associated with iterative testing.

5.4.1.3 Company C

Company C is an established car and motorcycle manufacturer. While CE principles and AI in product design are becoming increasingly important topics in the industry overall, their practical application in the context of design in Company C is rather limited.

Circular Design Strategies

Despite Company C manufacturing motorcycles to high standards, individual components require replacement from time to time. Therefore, the company designs and keeps a stock of spare parts to ensure that motorcycles can be maintained and repaired throughout their lifetime. According to the design expert, "maintenance is in the automotive industry [...] the most important design strategy" (DW, line 61-62). Nevertheless, the design expert

acknowledges that both Company C and the automotive industry for combustion engines predominantly adhere to the principles of a linear economy until today. According to DW, automotive and motorcycle manufacturers do not align with recycling companies for managing the end of a product's life. However, the case of electric vehicles is totally different, which underlines the importance of considering circular design strategies specifically within different industries, companies, products, and brands.

AI Applications

Company C is currently only using AI in the ideation phase. Based on previously designed motorcycle data, AI generates new graphic designs to provide designers with inspiration for novel motorcycle shapes and features. However, as confirmed by the design expert, this use of AI is applicable to any design and not yet used to account for circularity aspects specifically. Nonetheless, Company C's design expert sees huge potential in employing AI for simulating component lifespans, enabling smart maintenance and predictive repairs, or optimizing material usage.

5.4.2 Expert Interviews

This section outlines findings from six expert interviews. Expert interview transcripts are shown in Appendix D and interviewees are cited based on the first letters of the interviewee's first and last name.

Expert interviews complemented the findings of the case studies and identified three key AI applications when designing for product circularity. Insights from experts illustrate how AI is used for pattern recognition, predictions, and generative modeling. Based on the expert interviews, a summarized overview of AI applications and use cases is provided in Table A2 and Appendix A7.

Pattern recognition	Prediction	Generative AI
<ul style="list-style-type: none"> • Sustainable material recognition • Identification of country requirements • Usage pattern analysis 	<ul style="list-style-type: none"> • Simulation of product life cycle scenarios • Material impact predictions • Failure and downtime predictions • Strategic placement of components 	<ul style="list-style-type: none"> • Creation of novel material combinations • Personalized and novel designs

Table A2. AI Applications in Circular Product Design (Source: Own illustration)

Pattern Recognition

AI is a transformative force, significantly enhancing the analysis of large volumes of unstructured data and recognizing patterns within (Ellen MacArthur Foundation, 2019). Respondents noted three types of unstructured data - material, regulatory and usage - that can be better captured through AI. First, TE emphasizes the importance of understanding material composition, especially regarding factors such as CO2 emissions and recycling. Normally, there are no standardized formats for such material properties and not one all-encompassing database. Hence, AI plays a central role in seamlessly processing unstructured data from various databases, eliminating the need for labor-intensive manual efforts. Additionally, AI serves as a powerful research tool that explores and evaluates equivalent or alternative materials by recognizing material compositions and patterns based on past data. For instance, DK highlights that AI can propose circular alternatives, like aerated concrete with air bubbles for concrete façade design. This option has equivalent physical properties and patterns but minimizes resource and energy consumption. Second, CP mentions that different countries have different material requirements and regulations in place. AI has the potential to account for and find patterns in varying requirements and utilize those to tailor designs to meet, for instance, specific material standards in different countries. In turn, better compliance with regulations promotes the creation of products that are inherently better suited to the environmental and societal contexts of different regions. Third, MH highlights the current problem of missing feedback loops between product usage and design phase. According to

MH “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” (MH, line 158-159). TE and HK share the same view that AI helps to analyze and recognize consumer patterns, such as what drives product loyalty, how long products stay with people, how they are passed on, etc. Based on this data, designers can make more informed decisions and choose appropriate design strategies for different customers. Particularly designing for emotional durability can be improved based on consumer data. In essence, AI's transformative capabilities in managing and recognizing patterns in unstructured data, position it as a useful tool in the research phase and as a pivotal catalyst for advancing long and extended product life, and product recovery.

Predictions

By utilizing previously generated data, predictive AI simulates design decisions and consequently minimizes resource usage and waste in prototyping and testing (PdH). Expert insights underscore various ways how predictive AI significantly enhances product integrity. First, CP notes that sustainability often involves conflicting targets, such as the trade-off between reducing the carbon footprint and increasing water demand when transitioning from plastic to natural fibers, for example. Predictive AI excels in managing these conflicts by rapidly calculating and comparing the impacts of different scenarios, empowering designers to make informed material selections. Another aspect involves AI's capability to simulate product life cycle scenarios. For instance, in healthcare, AI facilitates simulations to test new protein and molecule structures, predicting their effectiveness against viruses or bacteria in a virtual environment (PdH). These approaches account for the main idea of increasing a product's lifetime. Moreover, AI can run sensitivity analyses and stress tests on materials and components to pinpoint potential errors and predict wear and tear, enabling designers to refine prototypes and uphold product integrity (TE). This aligns with AI's ability to forecast product performance, maintenance needs, and potential issues, allowing proactive scheduling of

maintenance and ensuring availability of spare parts designed in time. Lastly, AI aids in determining optimal component placements to facilitate ease of disassembly and repairability at the end of a product's lifecycle (DK). This is consistent with the ideas of extended product life and product recovery. To summarize, AI can make predictions in the prototyping and testing phase, allowing designers to consider possible future scenarios to boost long and extended use and recovery of the product in the first place.

Generative AI

While predictive AI focuses on forecasting outcomes based on existing data, generative AI creates new designs and solutions based on specified constraints and objectives. Specifically in the idea generation phase, generative AI encounters high potential by crafting new material compositions or creating unique, personalized designs based on user preferences (CP). First, generative AI generates innovative solutions by creating new material combinations aligned with predefined criteria. Unlike predictive approaches relying on historical data, generative material exploration involves the active creation of novel compositions, allowing designers to discover cutting-edge materials that meet circularity goals such as recyclability and reduced environmental impact (MH). An example from PdH references the European Space Agency's use of generative AI in crafting innovative metallurgical compositions (Ellen MacArthur Foundation 2019). Second, generative AI extends its influence to personalized circular designs, where it tailors products to individual user preferences (CP). By emphasizing the creation of entirely new and personalized solutions, generative AI empowers designers to consider factors like emotional durability (TE). This dynamic approach not only enhances the uniqueness of each design but also fosters a circular design ethos while increasing user satisfaction and product loyalty. This shows that generative AI has great potential to support designers in the ideation phase by suggesting inspiration and encouraging creativity.

5.5 Discussion

In answering the research question of how designers can effectively utilize AI to improve product integrity in the context of CPD, the key finding emphasizes the positive impact of AI applications on a product's integrity and circularity. This understanding resulted in the development of a comprehensive framework (Figure A1) that illustrates the relationship between AI and CPD, which ultimately contributes to product integrity. The framework illustrates the multiple applications of AI at different design stages and serves as an important tool to identify opportunities to improve product life, extend useful life and facilitate recovery - in line with the principles of the CE by den Hollander (2018). In-depth case study and expert interviews identified three different types of AI applications: Pattern recognition refers to the ability of a system to identify patterns or trends within data and to make informed decisions based on the identified patterns. Prediction is an application where algorithms are employed to forecast or estimate future outcomes based on historical data patterns. Generative modeling refers to a class of artificial intelligence applications that involve the creation of new content, designs, or solutions based on specified constraints and objectives. The proposal to strategically integrate these AI applications into the research, ideation and prototyping/testing phases offers a promising way to positively impact product integrity. As illustrated in Figure A1, the cumulative impact of AI applications (INPUT), manifests itself in improved product integrity as measured by long use, extended use, and recovery (OUTPUT). However, it is crucial to note that the step-by-step process of AI applications influencing the design phases and consequently product integrity can vary by industry, company, and product, as the case studies showed.

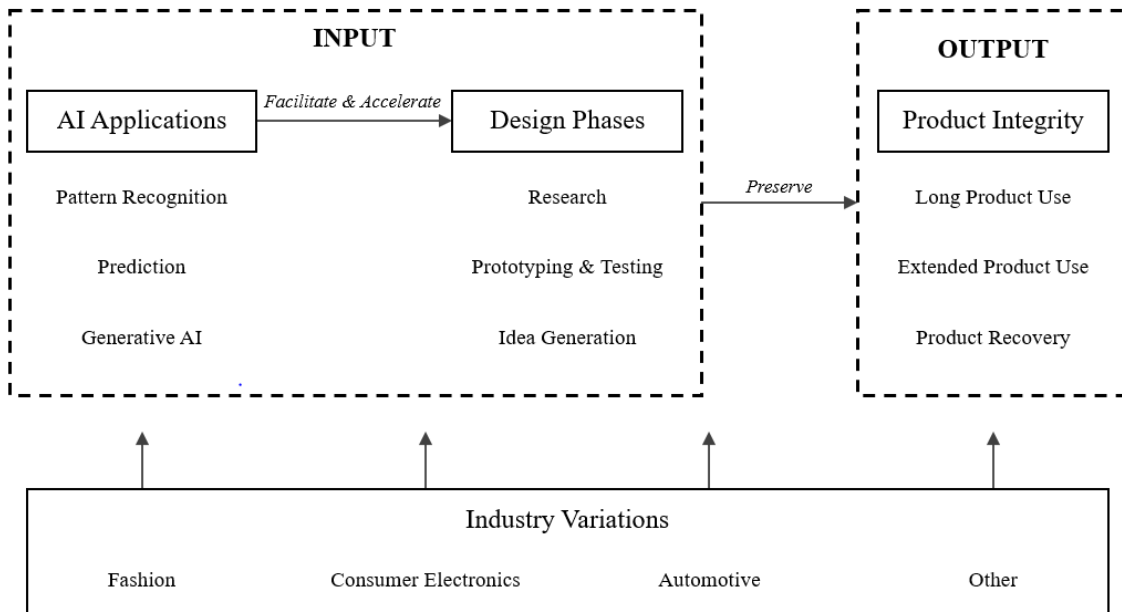


Figure A1. Framework for AI-enabled CPD (Source: Own illustration)

5.6 Theoretical and Practical Implications

This study holds significant theoretical implications for the literature fields of CE, CPD and AI. Most importantly, it offers insights into the collective impact of these fields, an aspect that has not been extensively researched to date. While the CE literature acknowledges the central role of digitalization, the specific applications of AI in CPD and its impact on product integrity remain relatively unexplored (Chauhan, Parida, and Dhir 2022; Kristoffersen et al. 2020). This study addresses this gap by introducing a novel framework that highlights the relationship between AI, product design and product integrity. In addition to the conventional emphasis on data analytics capabilities as noted by Roberts et al. (2022), this research uncovers additional AI applications for design, including pattern recognition, predictions, and generative modeling. Furthermore, the study underscores that AI-supported CPD has significant industry- and company-specific characteristics, with limited generalizability across sectors, companies, and products. This recognition of context-specific variations enriches the theoretical landscape, acknowledging the nuanced application of AI and CPD in different organizational and industrial settings. By shedding light on how specific AI applications can

contribute to CPD, this study provides CPD and AI scientists with a more comprehensive understanding of its potential benefits while addressing the need to consider both generalizable principles and industry-specific nuances. Additionally, the findings of this study carry significant practical implications and insights for both managers and product designers. First and foremost, the study highlights the relevance of AI in the design process and the interconnectedness of AI, design, and circularity. To meet the demands of CPD principles and AI technologies, designers should undergo upskilling programs tailored to align AI and design competencies with industry requirements. Recognizing the existing skill disparities, particularly with more conservative companies lagging behind agile start-ups, underscores the need for step-by-step AI incorporation and targeted training programs. Moreover, this research helps designers and managers to gain a nuanced understanding of various AI applications throughout CPD phases. This helps designers to leverage the power of AI in the right design phase. For instance, based on this research designers can leverage AI to find patterns in past data in the research phase or use AI to simulate end of life scenarios in the prototyping and testing phase. By leveraging AI and CPD principles correctly, decision-making is facilitated and the design process more efficient.

5.7 Limitations and Future Research

The research focuses on investigating product integrity within the CPD framework, as defined by Den Hollander (2018) (Figure A1). It intentionally excluded recycling as a CPD concept, emphasizing a potential avenue for future research to explore the relationship of AI and design for recycling in more detail. Next, this study analyzed only three exemplary companies as case studies, potentially limiting generalizability. Hence, future research could benefit from more comprehensive cross-industry case studies, making it more representative. It would also be desirable if future studies used a larger and randomized sample of experts to supplement and underline the findings presented in this study. Additionally, future research could investigate

more diverse stakeholders, such as end users. For example, potential areas for further research include how customers interact with AI-generated designs and how their perceptions of these designs could influence the success of circular design initiatives. Moreover, the study provides a snapshot of the companies' practices at a specific point in time. As technology and industry practices evolve rapidly, there is a need for longitudinal studies to capture temporal dynamics and assess circularity and effectiveness of AI interventions over time.

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

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

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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.

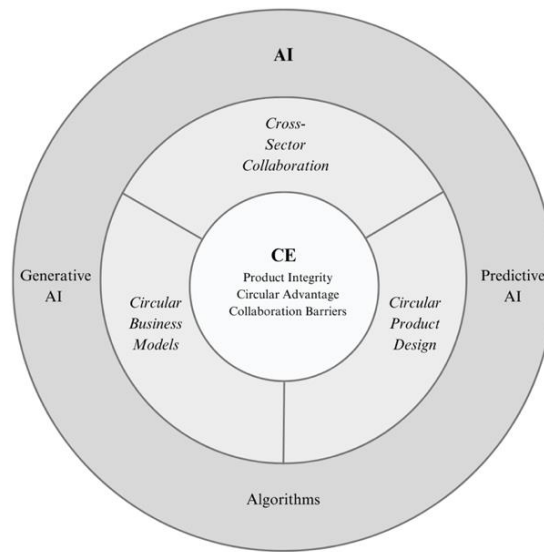


Figure 2. Circular Framework addressing AI's critical role to secure a more resilient and effective CE (Source: Own illustration)

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,

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encouraging circular consumption. Sentiment analysis gathers transparent customer feedback, shaping responsible business model. These integrated approaches foster sustainability, efficiency, and innovation within the Circular Economy framework. In the context of cross-sector collaboration, it becomes apparent that pattern recognition is the primary use case for this type of AI application. Using this application among collaborators expedites the establishment of synergies for goal setting and managing large amounts of unstructured data. The resulting alignment of interests ensures a stable foundation for C-SC. Additionally, AI can support the development of sharing platforms to structure collaboration. These platforms have proven to be crucial for customer-related use cases and are therefore also very important for circular business models.

Predictive AI has a significant potential for the CE. Specifically, in circular product design, it largely aids in conducting simulations. Predictive AI in product design thrives in managing sustainability trade-offs by swiftly calculating and comparing potential future product impacts. This can guide material selection decisions as well as how a product should be assembled. Moreover, predictive AI can conduct sensitivity analyses, refine prototypes, and ensures product integrity by predicting wear, enabling proactive maintenance scheduling, and facilitating end-of-life recovery. Next, predictive AI is also pivotal in circular business models, excelling in predictive maintenance and demand forecasting. It anticipates potential failures in industrial machines, manages remanufactured materials, and optimizes customer experiences in leasing models. Its capabilities extend to proactive recommendations for personalized training or product upgrades, notably in the manufacturing sector. Cross-sector collaboration also emphasizes the importance of time-series data, particularly in risk prediction and assessment. As different risk perceptions are found within the different sectors, predictive AI assists in evaluating and communicating these for an effective collaboration. Furthermore, it can assist in simulating decisions among collaborators in different sectors.

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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

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(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

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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

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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.

12 References

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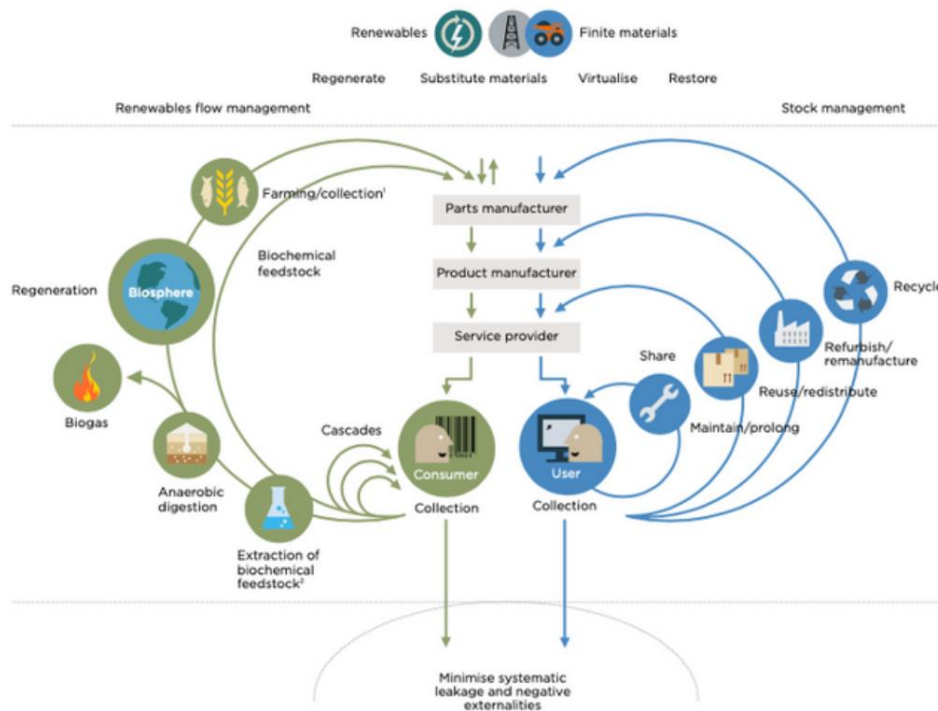
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Group Part

13 Appendix

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



1. Hunting and fishing

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

Group Part

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

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

Group Part

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

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

Group Part

Appendix A1. Overview of design strategies to slow and close the resource loop by Bocken, Nancy, Ingrid De Pauw, Conny Bakker, and B. Van Der Grinten. 2016. "Product Design and Business Model Strategies for a Circular Economy." *Journal of Industrial and Production Engineering* 33 (5): 308–20.

Design strategies to slow loop	Design strategies to close loop
<i>Designing long-life products</i> <ul style="list-style-type: none">• Design for attachment and trust• Design for reliability and durability	<ul style="list-style-type: none">• Design for a technological cycle• Design for a biological cycle• Design for dis- and reassembly
<i>Designing for product-life extension</i> <ul style="list-style-type: none">• Design for ease of maintenance and repair• Design for upgradability and adaptability• Design for standardization and compatibility• Design for dis- and reassembly	

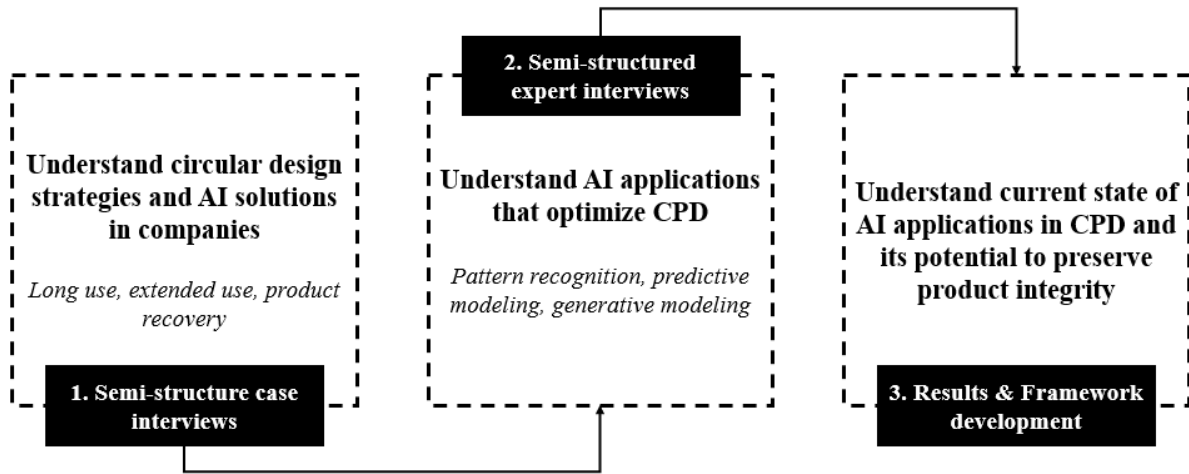
Group Part

Appendix A2. Circular design sub-strategies by Hollander, M.C. Den. 2018. “Design for Managing Obsolescence: A Design Methodology for Preserving Product Integrity in a Circular Economy.” *Delft University of Technology*, June

	Circular Strategies	Definitions from the Literature
Long use	Emotional Durability	Emotional durability is the ability of products to remain wanted by users over a long period of time.
	Physical Durability	Physical durability is the ability of products to withstand wear, stress, and environmental degradation and remain able to fulfil all physical functions for which it was designed over a long period of time.
	Maintenance	Maintenance is the performance of inspection and/or servicing tasks at regular intervals, to retain a product’s functional capabilities and/or cosmetic condition.
Extended use	Repair	Repair is the correction of specific faults in an obsolete product, bringing the product back to working condition, whereby any warranty on the repaired product generally is less than those of newly manufactured equivalents and may not cover the whole product, but only the component that has been replaced.
	Upgrading	Upgrading is the process of enhancing, relative to the original design specifications, a product’s functional capabilities and/or cosmetic condition.
	Recontextualizing	Recontextualizing is a term for use of an obsolete product (or its constituent components), without any remedial action, in a different context than it was used in as it became obsolete.
Recovery	Refurbishing	Refurbishing, or its equivalent reconditioning, is the process of returning an obsolete product to a satisfactory working and/or cosmetic condition, that may be inferior to the original specification, by repairing, replacing or refinishing all major components that are markedly damaged, have failed, or that are on the point of failure, even where the customer has not reported or noticed faults in those components. Generally, any warranty on a refurbished product applies to all major wearing parts but is less than that of a newly manufactured equivalent.
	Designing for Remanufacturing	Remanufacturing is a term for a series of industrial processes in a factory environment, whereby an OEM (original equipment manufacturer), an OEM contracted third party, or a third party licensed to carry the OEM brand name, disassembles obsolete products into components, to a level as far down as needed to bring as many of those components as considered eligible after testing back to at least OEM original performance specifications and recombines those components—generally originating from different used products—with as few as possible new parts, to manufacture new products of a similar type and specification, that result in a new product with a warranty that is identical to that of an equivalent product manufactured out of all new parts.

Group Part

Appendix A3. Research design for preserving product integrity through AI-based CPD (Source: Own illustration)



Appendix A4. Outline of the companies interviewed (Source: Own illustration)

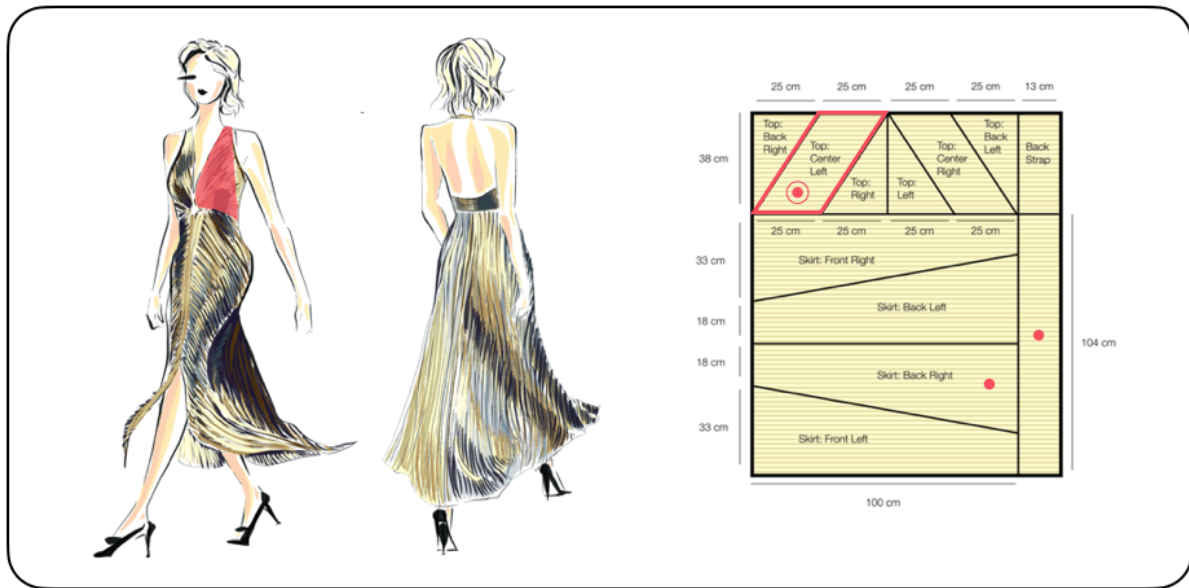
Organizations	Company characteristics	Employees	Industry
Case Company A	Boston-based start-up, turning leftovers and wasted textiles into zero waste clothing by utilizing the power of AI.	<10 in 2023	Fashion
Case Company B	Silicon Valley-based start-up, pioneering in AI and ML solutions for chip design and manufacturing.	<50 in 2023	Electronics
Case Company C	MNE, designing and manufacturing premium motorcycles and scooters, leveraging AI in the ideation phase.	>10,000 in 2023	Automotive

Appendix A5. Case study interviewee descriptives (Source: Own illustration)

Case	Day	Interview style	Person position	Years of experience	Length in minutes
A	November 9	MS Teams	Lead of Operations and Manufacturing	8	30
B	November 7	MS Teams	Design Engineer & AI Specialist	23	30
C	November 7	MS Teams	Product Designer	6	20

Group Part

Appendix A6. Zigzag design pattern for zero-waste fashion by “SXD | Zero Waste Design.” n.d.
<https://www.sxd-ai.com/>.



Group Part

Appendix A7. Key findings on AI use cases for CPD. (Source: own illustrations)

AI application segmentation	AI use cases	Circular design strategy
Pattern recognition	Sustainable material recognition	<ul style="list-style-type: none"> • Design for recovery
	Identification of country requirements	<ul style="list-style-type: none"> • Design for long use • Design for extended use • Design for recovery
	Usage pattern analysis	<ul style="list-style-type: none"> • Design for long use • Design for extended use
Prediction	Simulation of product life cycle scenarios	<ul style="list-style-type: none"> • Design for long use • Design for extended use • Design for recovery
	Material impact predictions	<ul style="list-style-type: none"> • Design for long use • Design for extended use
	Failure and downtime predictions	<ul style="list-style-type: none"> • Design for long use • Design for extended use
	Strategic placement of components	<ul style="list-style-type: none"> • Design for recovery
Generative AI	Creation of novel material combinations	<ul style="list-style-type: none"> • Design for long use • Design for recovery
	Personalized and novel designs	<ul style="list-style-type: none"> • Design for long use

1 **Appendix D1.** CP's interview transcript

2
3 **CP**
4 Hello, thanks for inviting me today. My name is CP. I'm a senior expert in the field of
5 sustainability. I've worked mostly in the automotive industry in the sustainability space for
6 more than 10 years now. Since 2019, I was subject matter leader for the field of circular
7 economy, mostly in the space of the automotive industry, but also branching out to other
8 consumer products such as glasses or cables. My education background is engineering. But
9 that's, uh, doesn't uh contribute much, so I'm very happy to to answer questions.

10
11 **Lena Sophie Thielmann**
12 Thank you very much. Very nice to meet you and let's start right up with the first question
13 being how do you see the current developments in circular economy in general?

14
15 **CP**
16 The current developments for circular economy are maybe to be seen in two dimensions.
17 First, there is a lot of hope around circular economy as resource efficiency becomes more
18 tangible across all sectors of industry, that's the one world.
19 So there's a lot of sort of hype around it.
20 The second site that I see is that it's hard, at least for companies to actually implement
21 circular changes, because well, I wouldn't say the reasons already, but it's hard to implement,
22 so a lot of hype and hard to implement would be the summary on how I see the current
23 space.
24 That comes mostly from an industry out of long lasting consumer products like cars and we
25 always try to do segments of what do you have in terms of what's the average lifespan of the
26 product or the company that you're looking at.
27 Let's see from a car or even a ship or machine with 10 plus years of investment to single use
28 straw for instance.
29 So that needs to be differentiated in that spectrum maybe?

30
31 **Lena Sophie Thielmann**
32 And did you have like, an impression on how AI is currently developing in the field or do
33 you have any experience in that regard?

34
35 **CP**
36 What we could see in the past is that circular economy had a lot of hurdles to.
37 To get implemented the second part that I'm in the question now is how?
38 How AI can work and maybe we need to see how technology or digital technologies in
39 general can help and then how AI specific can help.
40 I would look at that in two stages and for the automotive industry, one of the big challenges
41 in the field of data and technology was the availability of data and quite literally the email I
42 sent 30 seconds before we met was to an automotive company on trying to understand their
43 data on their materials.

Group Part

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

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

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

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

50 This is now speaking for the large consumer.

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

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

57

58 **Lena Sophie Thielmann**

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

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

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

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

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

69

70 **CP**

71 Mm-hmm.

72

73 **Lena Sophie Thielmann**

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

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

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

79

80 **CP**

81 Mm-hmm.

82

83 **Lena Sophie Thielmann**

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

86 So that would be probably your field of expertise.

Group Part

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

89

90 **CP**

91 Alright, understood.

92

93 **Lena Sophie Thielmann**

94 OK.

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

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

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

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

101

102 **CP**

103 Mm-hmm.

104

105 **Lena Sophie Thielmann**

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

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

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

125

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

Group Part

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

131

132 **CP**

133 OK.

134 That's good.

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

138

139 **Lena Sophie Thielmann**

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

145

146 **CP**

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

152

153 Then let's see what we can do with the first one. Temporary dynamics of technology. So the
154 differences with the different partners. Umm, I will put that in the top left. Why is that?

155 Because the further you go down the supply chain, the more you find differences. There's
156 huge differences in technology that will work and this also across actors, like the chemistry
157 industry is way, way far advanced and the automotive industry.

158

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

161

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

164

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

168

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

Group Part

172
173 Misaligned interests, that is, maybe even above #1 because a lot of businesses and business
174 models depend on the linear business models with fast consumption. Think fast fashion for
175 instance. There's very little incentive for repairability. Just try to fix jeans again, it's just
176 impossible.
177 #7 absence of system standardization and performance management. That's a huge one
178 where I invite you to look into the catina ex activities that the European or German industry
179 is doing. It's between one and three. Ah, no, it might be even higher to be honest, because it
180 makes it painful and also slow if the different actors don't speak the same language in terms
181 of standards.
182
183 #8 Risk management. Put it next to #3. Because here, particularly in the automotive space,
184 the designer wants to introduce more recycled metals for certain parts and then the customer
185 safety aka vehicle safety was always an obstacle there.
186
187 And then we have poor demand, acceptance of environmentally superior technologies. That
188 goes on the same level as six and seven because here we need to see that very often only
189 because something is recycled it's not necessarily better for the environment.
190
191 #10, inflexible policy and structure. This is a problem next to three and eight. I am thinking
192 about material regulations. A huge obstacle in terms of plastic recycling that cars or even
193 Lego bricks that have been produced 20 years ago due to changed legislation that can't be
194 recycled anymore nowadays. So they need to be burned.

195
196 **Lena Sophie Thielmann**

197 OK.
198 Thank you.

199
200 **CP**

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

202
203 **Lena Sophie Thielmann**

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

211
212 **CP**

213 OK.
214 OK, then let's move them around.

Group Part

215 Number one, temporal dynamics of technology I think here because it's faster, it must be in
216 the right very far, very far right, because yeah, I would hope that AI helps to work with that
217 speed.

218 Distinct operational management practices #2 I would leave it pretty much where it is.
219 #3 again. Uh, at least in the middle, but let's think about that. Monitoring performance
220 within multiple context, maybe even higher, we can put on the line between section 2 and
221 Section 3.

222 Risk of information loss. I would hope that AI is on the same level as number one. To help
223 that information doesn't get lost and is handled with care.

224 Uh #5. You can shift it on the same line but on the right side next to number one. I would
225 hope that AI would help, particularly to get more speed on disclosures

226 #6 Misaligned interest of actors.

227 There I think AI has not much impact or can't much because it is a people problem.

228 #7 we can shift into the middle from my point of view even maybe more on the line. Again
229 on the same level as three, because with absence of systems of standards, maybe AI can help
230 to accelerate this.

231 #8 we can push it in the middle. Uh, right in the center of the of the of the map, because here
232 AI might have the chance to help with some transparency things to make risks more visible
233 in their context.

234 Moving to 9 it is mainly only in communication. Nine, we have to push even a bit inwards.

235 And then inflexible policy and structure. Think we can put a bit to the left? I don't see how
236 AI can help with the policies unless AI helps to understand the policies and finds a way to
237 basically like to a black list or white spot analysis on where analysis is. Put it maybe a bit on
238 the line between one and two. Umm for the aspect where AI can help to identify white spots
239 in the legislation so I can put certain product there.

240

241 **Lena Sophie Thielmann**

242 I thank you so much for your insights and your sharing of your experience.

243 And before we start with the second individual part, my last question would be, do you miss
244 any specific barrier?

245 Is there anything you think off in the field of cross sector collaboration, CE and AI?

246 Do you think there's something missing in this regard?

247

248 **CP**

249 Good question.

250

251 Do we have regulation?

252

253 **Lena Sophie Thielmann**

254 Not specifically at the moment.

255

256 **CP**

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

Group Part

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

267

268 **Lena Sophie Thielmann**

269 Umm, OK, thank you very much.

270

271 **CP**

272 You're welcome.

273

274 **Lena Sophie Thielmann**

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

276

277 **Annelie Sophie Steinbrenner**

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

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

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

285

286 **CP**

287 I worked in R&D for two years and was involved in the product design there as well.

288 I think there's generally 2 approaches that you can take. One would be design for durability,
289 which means the product will never break and the lifespan is very long. Let's make it
290 tangible. Let's say the iPhone lasts seven years or something and you don't need to have it
291 repaired. That would be great.

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

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

296

297 **Annelie Sophie Steinbrenner**

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

Group Part

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

306

307 **CP**

308 Yeah. Thank you. That's good.

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

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

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

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

319

320 **Annelie Sophie Steinbrenner**

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

327

328 **CP**

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

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

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

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

340

341 **Annelie Sophie Steinbrenner**

342 That helps a lot, yeah.

343

344 **CP**

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

347

Group Part

348 **Annelie Sophie Steinbrenner**

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

351

352 **CP**

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

355

356 **Annelie Sophie Steinbrenner**

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

361

362 **CP**

363 That's a good one.

364

365 **Annelie Sophie Steinbrenner**

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

370

371 **CP**

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

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

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

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

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

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

Group Part

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

399

400 **Annelie Sophie Steinbrenner**

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

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

404

405 **CP**

406 Yes.

407

408 **Annelie Sophie Steinbrenner**

409 Perfect. Thank you very much.

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

412

413 **CP**

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

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

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

427

428 **Annelie Sophie Steinbrenner**

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

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

432

433 **Lena Maria Pertz**

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

436

Group Part

437 **CP**

438 The essential differences are bitter, everyone wants a linear business model and no one
439 wants a circular business model, so that's bitter, because sometimes trying to describe, in my
440 opinion, the circular business models need significantly more foresight, so the planning
441 horizon is longer than that. In the linear business models and depending on the type of
442 company, size, shareholders, structure and how the management is staffed, the incentives
443 have comparatively short cycles and thus makes it difficult, so if you think in 6 quarters,
444 then it will be difficult to break up the entire year from the business model.

445 Circular, for example, with a planning horizon of 10 years.

446 So, that is, to answer the question simply, the required foresight and doubts also the
447 complexity of the business model, are the 2 biggest differences.

448

449 **Lena Maria Pertz**

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

452

453 **CP**

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

460

461 **Lena Maria Pertz**

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

464

465 **CP**

466 You would have to differentiate between segments, i.e. industrial segments.

467 My biggest insight into the automotive sector, which is why I keep coming back to
468 automotive. Now I'll have to see how this is seen in your context.

469 Before Corona, I had the impression, but then subjective impression, that companies had
470 enough money and foresight to tackle long-term things.

471 With Corona, everything suddenly went into crisis mode because my supply chains
472 completely collapsed. Companies had to react much faster.

473 And that's pretty much my subjective perception that the projects or the activities that
474 support circular business models have been put on the back burner.

475 Unfortunately, the last 2 years with the war have not contributed to the fact that the situation
476 has changed, so that is my basic impression. Nevertheless, there is a driver in the context,
477 which is regulation, so look at it and then you have to differentiate exactly from when is a
478 business model circular and at what point did I simply implement recycling legislation?

479

Group Part

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

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

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

489 In Germany, I find Lidl interesting, Lidl why?

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

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

500

501 **Lena Maria Pertz**

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

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

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

512

513 **CP**

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

517

518 **Lena Maria Pertz**

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

Group Part

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

525

526 **CP**

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

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

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

540

541 **Lena Maria Pertz**

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

547

548 **CP**

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

552

553 **Lena Maria Pertz**

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

557

558 **CP**

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

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

Group Part

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

570

571 **Lena Maria Pertz**

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

577

578 **CP**

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

585

586 **Lena Maria Pertz**

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

589

590 **CP**

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

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

598 Training and Consulting. But how about behavioral change?

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

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

604

605 **Lena Maria Pertz**

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

Group Part

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

611
612 **CP**

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

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

618 Unless, of course, you go into the topic of AI advertising, sensitization, customer and take
619 them away from maybe even a topic, not even honestly really bitter.

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

623 Yes, that's a steep hypothesis.

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

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

631
632 **Lena Maria Pertz**

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

637
638 **CP**

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

644
645 **Lena Maria Pertz**

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

650
651 **CP**

Group Part

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

656

657 **Lena Maria Pertz**

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

672

673 **CP**

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

678

679 **Lena Maria Pertz**

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

684

685 **Lena Sophie Thielmann**

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

1 **Appendix D2.** MH's interview transcript

2

3 **Annelie Sophie Steinbrenner**

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

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

14

15 **MH**

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

24 I left Accenture 7 years ago and founded my own company. Together with 3
25 friends/colleagues, we set up a consultancy that focused on strategy, digital technology, and
26 sustainability, particularly in the circular economy. I was a partner and co-founder of the
27 company for the first 5 years and worked a lot there, especially at this interface between the
28 3 topics, together with various companies.

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

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

44 **Annelie Sophie Steinbrenner**

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

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

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

60

61 **MH**

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

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

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

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

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

Group Part

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

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

93

94 **Annelie Sophie Steinbrenner**

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

101

102 **MH**

103 Many companies have a lot of excuses as to why things can't work in their industry. I read a
104 very interesting article yesterday. About fast tech. That was the first time I'd really heard the
105 term. I had heard of fast fashion, but I had never heard of fast tech. I don't know if you have
106 an iPhone. I come from the time when you had a Nokia, and you could go to the nearest
107 kiosk and buy a new battery when the battery stopped working and then you replaced it
108 yourself or you could open the phone and replace other things yourself. So back then, the
109 Nokia was built for recovery and extended use. At some point, Apple then said, well, we're
110 going to make the thing so tight that every time you have to replace the battery, you have to
111 break the front screen and break a lot of other things. And that's why it's often not worth
112 repairing. That's why I firmly believe that the concept of longevity and extended use is
113 possible in all areas. However, we

114 have to think differently in different areas, i.e., in different areas I have to think ok, how can
115 I repair a product to make it usable for longer? In other areas, on the other hand, as you have
116 said very nicely here, the question of how can I keep the product attractive for a longer
117 period is more important? In other areas, I have to think about how I can make the product
118 suitable for reuse. Or how can I set up a second-hand market? These are all different
119 perspectives.

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

Group Part

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

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

138

139 **Annelie Sophie Steinbrenner**

140 All right, well, I've understood.

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

145

146 **MH**

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

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

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

169 These are perhaps 3 starting points.

170

171 **Annelie Sophie Steinbrenner**

Group Part

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

175

176 **MH**

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

181

182 **Annelie Sophie Steinbrenner**

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

185

186 **MH**

187 Yes, genua. Exactly. Exactly.

188

189 **Annelie Sophie Steinbrenner**

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

193

194 **Lena Maria Pertz**

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

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

Group Part

215

216 **MH**

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

233

234 **Lena Maria Pertz**

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

236

237 **MH**

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

256

257 **Lena Maria Pertz**

Group Part

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

263

264 **MH**

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

277

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

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

297

298 **Lena Maria Pertz**

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

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

303

304 **MH**

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

317

318 **Lena Maria Pertz**

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

321

322 **Lena Sophie Thielmann**

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

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

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

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

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

336 But what is the current situation in the market?

337

338 **MH**

339 Mhm.

340

341 **Lena Sophie Thielmann**

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

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

346

347 **MH**

348 Yes, I looked at it beforehand.

349 I found it very exciting to go through the different barriers and also to try to place them on
350 the X and y axis.

351 It's not easy, but it's definitely an interesting way of looking at it.

352 Shall we go through from 1 to 10 and I'll say a bit about all of them?

353

354 **Lena Sophie Thielmann**

355 Yes please.

356

357 **MH**

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

360

361 **Lena Sophie Thielmann**

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

364

365 **MH**

366 So I can see the problem here very clearly.

367 A long time ago, we spoke to Alko, the alcohol monopolist here in Finland, and one of their

368 tasks is to create transparency about their wines and their sustainability. Then we discussed

369 how we could present an end-to-end view of the wines. From the vine that is picked to the

370 rural end product, where we quickly realized that a winegrower somewhere in South

371 America might not even have an internet connection. How is he supposed to enter data about

372 his vines into a database that Alko can then use?

373 This means that there is very often a serious difference in the status of the technologies in a

374 global supply chain, which you have to cover in the circular economy because I have to

375 work with a lot of partners, so this is a very important point. Where there is definitely an

376 approach. Now the question is whether AI is the right technology to address this or are

377 topics such as blockchain or similar topics more important? But I think that AI at least, I

378 wouldn't put it on the high side, I would probably put it on the somewhat lower side, I don't

379 know exactly how AI could play a serious role there.

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

381 But in my view, they are a general problem that companies have along their value chain, as

382 there are very different practices.

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

384 Yes, AI can of course help to translate and adapt the practices, so probably more on the

385 lower third in terms of their current urgency for collaboration and then on the right-hand

386 side.

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

389

390 **Lena Sophie Thielmann**

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

395

396 **MH**

397 Yes, so when it comes to targets, I saw that in point 6 as well, the mismatch of targets.

398 It's a huge problem that different parties in the supply chain have different goals, incentives
399 and operating environments when it comes to this. This is a huge problem in the circular
400 economy, because companies are of course optimizing themselves in many areas.

401 I would say AI can of course help here, so I think the positioning is already quite good,
402 perhaps a little further to the right, but not on the high side either.

403 The loss of information I believe, and this includes the question of information processing,
404 because the problem is often, as I have already mentioned, that the amount of information is
405 often so large that it cannot be processed and that this results in a loss of information.

406

407 **Lena Sophie Thielmann**

408 Exactly.

409

410 **MH**

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

416

417 **Lena Sophie Thielmann**

418 Do you think that the status that AI has today could reach its limits if you think about the
419 really diverse partners that would want to work together, such as public institutions with
420 private companies, could AI reach its limits in a certain way in the current context?

421 Or do you think AI is still very, very well positioned in this regard at the moment?

422

423 **MH**

424 It's a difficult question because, of course, it's often about what questions I ask and then
425 that's a completely different discussion.

426 The topic of AI is also a completely separate, stand-alone issue.

427 Today, companies often go in and say: we collect all the data and then we simply ask what
428 the data can tell us, which is of course a completely stupid question. Collecting all the data

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

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

432 Furthermore, development is progressing very, very quickly at the moment. Be it in the field
433 of supercomputers or quantum computers, I don't think we'll reach our limits any time soon.

434 The problem from my point of view is point 5, which is an incredibly big problem.

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

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

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

461

462 **Lena Sophie Thielmann**

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

465

466 **MH**

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

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

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

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

524

525 **Lena Sophie Thielmann**

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

532

533 **MH**

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

540

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

546

547 **Lena Sophie Thielmann**

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

552

553 **MH**

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

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

570

571 **Lena Sophie Thielmann**

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

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

577

578 **MH**

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

583 In principle, the topic of data as a basis, which AI is based on, is a huge topic in the circular
584 economy at the moment. Because it's about material flows and I need to understand how
585 these material flows behave across company boundaries and geographic borders. This means
586 that it is often not a problem of AI that we are talking about, but rather a problem of data
587 sharing or data collection, of data availability, on which the problem of AI is then based.

588 In other words, the issue I mentioned of collecting data along the value chain is not an AI
589 problem once we have the data from the wine farmer in South America to opening a bottle
590 of wine on the sofa in the evening. Then we can put AI on it and understand where we can
591 make certain optimizations, where we can do certain things along the value chain.

592

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

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

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

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

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

616

617 **Lena Sophie Thielmann**

618 Yes, for sure.

619

620 **Annelie Sophie Steinbrenner**

621 I have a question about that. I find the last point very interesting. We've already tried this a
622 bit by saying that we can't look at the entire value chain. We can't look at every aspect of the
623 circular economy. But I had the feeling that you thought we were still not defined enough.

624 Because it's still too broad, in my case, for example, product design, did I understand
625 correctly that you could go into the individual topics more specifically in order to define
626 these starting points?

627

628 **MH**

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

635 Plus all supply and plus all customers etc.

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

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

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

651

652 **Annelie Sophie Steinbrenner**

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

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

659

660 **MH**

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

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

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

667

668 **Lena Maria Pertz**

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

Group Part

1 **Appendix D3.** DK's interview transcript

2

3 **Lena Maria Pertz**

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

6

7 **DK**

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

14

15 **Lena Maria Pertz**

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

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

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

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

31

32 **DK**

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

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

40 Andthe second question would be?

41 Let's talk about the circulating business models or secular business mode in the propersense.

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

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44 You can extend to the product lifecycle files and so on and so forth, which is a more
45 sustainable or circular business model, but not a classic up use case of security.
46 Or to put it another way a signed business model is the knowledge model, which would not
47 work without circular value creation.
48 And a circular business model is a business model that could go on without these circular
49 elements. And there is the question, what is, what is the focus here?
50

51 **Lena Maria Pertz**

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

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

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

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

63 This is really pure circle business models that have the main value proposition to operate in
64 a circular manner from the ground up. In order to continue, so as I said, I then picked out
65 processes from this circle business model that are indispensable in a circle up to the model.
66 The I wanted to ask you at this point. With these 7 that are listed here, if you are still
67 missing any one component simpler.
68

69 **DK**

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

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

78 So one point I would rephrase, which is the third point in general Environmental
79 Management Systems and one more point I would add, which would be directly linked to
80 this Environmental Management System, an environmental BI and environmental
81 Advanced Analytics and that could also be called AI.
82

83 **Lena Maria Pertz**

84 Ah, ok, understood, okay, so that would be 2 extra components to be added, so to speak.
85

86 **DK**

Group Part

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

88

89 **Lena Maria Pertz**

90 Exactly, okay, yes, yes.

91

92 **DK**

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

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

101

102 **Lena Maria Pertz**

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

109

110 **DK**

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

126

127 **Lena Maria Pertz**

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

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

135
136 **DK**
137 Take Back System is something like taken back and refurbished or built on elements and
138 then these elements are then installed in the new product.
139 I don't think so, it's more of a design and technical topic at most in the basic text. If we look
140 at this business model for several years now, you can use data to determine which elements
141 will be replaced, so in most cases. So it's completely thrown away, or what elements have to
142 be produced afterwards, and you can then practically reproduce it in advance, you know, if I
143 send such an Apple piece back, this attachment, this little piece can be thrown away, but the
144 rest is then kept in the cycle and accordingly this little component and afterwards has to be
145 produced.

146
147 **Lena Maria Pertz**
148 Thank you very much for that and then I know that I have often read that it is particularly
149 important in the silent economy that you leave the customer in the feedback loop, that co-
150 creation happens with the customer.
151 To what extent do you see this point, especially in the circle economy, this is an important,
152 important aspect.

153
154 **DK**
155 Oh, that's definitely an important aspect.
156 But I would expand on it a bit and say that it's not just customers, i.e. these, who need
157 communication, but at the same time we also need courageous, multilateral communication
158 between different stakeholders, but are the requirements of the customers, that's very
159 important, like the communication or like C communication, but at the same time what are
160 the responses of the suppliers?
161 Yes, because you have to ask with the suppliers, you have to talk to energy, suppliers and so
162 on and so forth, so that you have such a practically holistic, communication strategy, once
163 bilaterally and once multilaterally all together and maybe by the way. We recently had an
164 IOP, which would be a large corporation and says makes us an offer on a specific topic. And
165 there was the topic They wanted to have a collaboration management system for circular
166 economy and environmental data, because they said ok circular economy and ESG can't be
167 solved alone. We have to talk to everyone and at the same time, and that's where we need a
168 collaboration platform like this.
169 It's just by the way.

170
171 **Lena Maria Pertz**
172 Mhm yes, no, that's especially important for the last topic that Lena discusses later, so it's

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

182

183 **DK**

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

190

191 **Lena Maria Pertz**

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

194

195 **DK**

196 Yes, probably later again, but now the current state of chatbots.

197 Bots that's the sind yes great, stupid you have to honestly say that yes, so these are now
198 practical very, it has to be a very standardized process, because with chatbot works
199 otherwise that's just annoying.

200

201 **Lena Maria Pertz**

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

206

207 **DK**

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

211

212 **Lena Maria Pertz**

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

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215

216 **DK**

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

238

239 **Lena Maria Pertz**

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

244

245 **Lena Sophie Thielmann**

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

247

248 **DK**

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

250

251 **Lena Sophie Thielmann**

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

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

300

301 **Lena Sophie Thielmann**

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

304

305 **DK**

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

312

313 **Lena Sophie Thielmann**

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

318

319 **DK**

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

324

325 **Lena Sophie Thielmann**

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

332

333 **DK**

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

341

342 **Lena Sophie Thielmann**

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

347

348 **DK**

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

356

357 **Lena Sophie Thielmann**

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

359

360 **DK**

361 So from a regulatory perspective, we now have this obligation to exchange and disclose data
362 due to certain directives. At the same time, I at least see a willingness in the industry to
363 share data with each other, because if we share the data, we can also report better and
364 coordinate our coordination on the circular economy better. A good example is Catena X.
365 This is an association of different automated stakeholders who then exchange the data and
366 enrich it with AI, making it practically a shared data platform.

367 Therefore, the chance of acceleration is rather high and I would say the immediate
368 significance for CE is medium.

369

370 **Lena Sophie Thielmann**

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

372

373 **DK**

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

377

378 **Lena Sophie Thielmann**

379 Okay, great.

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

384

385 **DK**

Group Part

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

394

395 **Lena Sophie Thielmann**

396 Yes, exactly.

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

401

402 **DK**

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

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

414

415 **Lena Sophie Thielmann**

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

419

420 **DK**

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

427

428 **Lena Sophie Thielmann**

Group Part

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

434

435 **DK**

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

443

444 **Lena Sophie Thielmann**

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

447

448 **DK**

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

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

461

462 **Lena Sophie Thielmann**

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

465

466 **DK**

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

470

471 **Lena Sophie Thielmann**

472 Okay, I see.

473

474 **DK**

475 At least that's my opinion.

476 I would be against AI doing anything.

477

478 **Lena Sophie Thielmann**

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

481

482 **Annelie Sophie Steinbrenner**

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

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

491

492 **DK**

493 No, well, I already know that.

494

495 **Annelie Sophie Steinbrenner**

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

498

499 **DK**

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

502

503 **Annelie Sophie Steinbrenner**

504 To be honest, no.

505

506 **DK**

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

508 Can I briefly share my screen?

509

510 **Annelie Sophie Steinbrenner**

511 Yes logically. Just a moment.

512

513 **DK**

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

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

527
528 **Annelie Sophie Steinbrenner**

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

531
532 **DK**

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

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

543
544 **Annelie Sophie Steinbrenner**

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

553
554 **DK**

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

564
565 **Annelie Sophie Steinbrenner**

Group Part

566 Understood. Some research papers have already shown a few areas that can definitely be
567 improved by AI. Maybe now, when you look at that, where do you see the biggest
568 opportunities to actually use AI in the individual circular strategies?
569

570 **DK**

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

572 Accessibility is less AI.

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

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

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

580 Ergonomics rather not.

581 Fault isolation, yes, definitely that.

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

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

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

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

590 Connection selection. Then the potential for AI would be high

591 Functional integration is definitely very high.

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

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

597 Manufacturing. Definitely high.

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

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

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

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

605 Structural design is definitely very important.

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

608 Documentation, identification, monitoring, standardization.

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

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

613

614 **Annelie Sophie Steinbrenner**

Group Part

615 Okay, let me ask you once again if that was the right understanding? So you would also say
616 that this topic of prototyping is super relevant? Precisely through building information
617 modeling and that probably counts mainly in concept design and embodiment design, right?
618

619 **DK**
620 Yes.

621
622 **Annelie Sophie Steinbrenner**
623 And this other topic with tracking, that's being mentioned more and more often precisely the
624 designer incorporating a digital twin, for example, to see when what no longer works?
625 Would you consider digital twins and predictive maintenance, for example, to be part of the
626 design or business model?
627

628 **DK**
629 Well, I think they are both topics at the same time, because on the one hand, when we install
630 something, it's a technical topic. Because if we install a sensor somewhere, a space has to be
631 created for this sensor and so on. So it's design-driven. At the same time, this sensor carries
632 something and then we are in the area of predictive maintenance and so on, which tends to
633 involve business models. So I think that plays a role in both areas.
634

635 **Annelie Sophie Steinbrenner**
636 Cool. That was very, very interesting. Thank you very much, I think I'm done with my part
637 and we're already well advanced in time. Last but not least, I'll now hand over to Lena P.
638

639 **DK**
640 I was also pleased to hear that you can send me the results when the Master's thesis is
641 finished.
642

643 **Lena Maria Pertz**
644 Yes, we are very happy to do that. So thank you again from my side for your time and for
645 your insights. I think we can use and reflect a lot in our thesis. If we have any further
646 questions, we'd be happy to get back to you, but I think that's all we need to know for now?
647 Do you still have any questions?
648

649 **DK**
650 Maybe which companies have invited you for interviews.
651

652 **Lena Maria Pertz**
653 Very different ones, so of course we have already tried to find stakeholders who have
654 experience in both areas, which is of course very difficult. In fact, we realized that we were
655 all the more pleased that we were able to acquire you, so to speak. Accordingly, we have a
656 relatively large number of people who are only involved in the circular economy. Many
657 from consulting firms, so we had Accenture, then Porsche Consulting... I think Annelie had
658 some that were particularly specialized in product design.
659

660 **DK**
661 Mhm, okay, well yes definitely sounds cool, so good mix.
662 But that's not three master's theses, is it?
663

Group Part

664 **Lena Maria Pertz**

665 Exactly, yes.

666

667 **DK**

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

669

670 **Lena Maria Pertz**

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

672

673 **Lena Sophe Thielmann**

674 Thank you very much.

675

676 **DK**

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

678

679 **Annelie Sophie Steinbrenner**

680 Thank you ciao.

681

682 **Lena Maria Pertz**

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

1 **Appendix D4.** TE's interview transcript

2
3 **Lena Sophie Thielmann**
4 Hello [REDACTED], thank you very much for taking the time to talk to us today. It would be nice
5 if you could start by briefly introducing yourself.

6
7 **TE**
8 With pleasure. I was at McKinsey for more than 13 years and have now been at Camelot for
9 about 5 years, where we do supply chain consulting. It's not necessarily focused on
10 sustainability, but sometimes it has aspects of sustainability. The topic is of course becoming
11 increasingly important, which is why we have many people in the team who deal with it in
12 great detail. And I come from Düsseldorf. So, let's get started, shall we?

13
14 **Lena Sophie Thielmann**
15 Great, then I'll share my screen briefly. So the background to my topic: I looked at the topic
16 of cooperation within the topic of circular infrastructure, i.e. how can you really close the
17 loop in the end and how can AI support this. And I quickly came up with the topic of
18 cooperation, precisely because this transition is a huge obstacle for companies alone and you
19 also have to work together with your supply chain, but also with different sectors, in order to
20 be able to take this step towards a circular economy. In my research, I came up with 27
21 barriers to cross-sector collaboration in the circular economy, 17 of which were said in the
22 research to be overcome by Industry 4.0 technologies and working methods. However,
23 Industry 4.0 is not AI per se and that's why I then looked again at which of these 17 barriers
24 AI can really make a contribution to and build on.

25
26 **TE**
27 Mhm.

28
29 **Lena Sophie Thielmann**
30 And that's why I came up with this selection of 10 barriers and my idea now would simply
31 be to go through the individual barriers and look at the y axis to see what their immediate
32 significance for the circular economy really is. Perhaps you have already gained other points
33 of experience because the barriers are currently based purely theoretically on research and
34 then, in the second step, look at the x axis to see, what is the real opportunity that AI has for
35 these barriers?

36
37 **TE**
38 Mhm. Okay understood.

39
40 **Lena Sophie Thielmann**
41 Exactly then I would just say we start directly with the first point, I would just briefly
42 introduce the points and then maybe you can give your opinion.

43

44 **TE**

45 Yes.

46

47 **Lena Sophie Thielmann**

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

52

53 **TE**

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

55

56 **Lena Sophie Thielmann**

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

61

62 **TE**

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

64

65 **Lena Sophie Thielmann**

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

70

71 **TE**

72 Thanks, Mhm.

73

74 **Lena Sophie Thielmann**

75 So it's really this whole picture of collaboration as you can envision it and it's just that
76 performance monitoring is completely different for these individual parties.

77 With point 4, we have the risk of information loss because people are not fully aware of
78 what information do I need to share? How is this handled?

79

80 **TE**

81 Mhm.

82

83 **Lena Sophie Thielmann**

84 This also extends a little into the point 5, so to speak, that there is simply a reluctance to
85 share information. People are hesitant about it.

Group Part

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

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

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

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

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

99

100 **TE**

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

102

103 **Lena Sophie Thielmann**

104 Yes exactly.

105

106 **TE**

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

109

110 **Lena Sophie Thielmann**

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

115

116 **TE**

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

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

Group Part

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

145

146 **Lena Sophie Thielmann**

147 Yes, you're absolutely right.

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

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

153

154 **TE**

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

157

158 **Lena Sophie Thielmann**

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

160

161 **TE**

162 Okay, so it's very important for CE.

163

164 **Lena Sophie Thielmann**

165 Mhm.

166

167 **TE**

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

Group Part

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

180
181 **Lena Sophie Thielmann**

182 Do you see that as a big risk?

183
184 **TE**

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

189
190 **Lena Sophie Thielmann**

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

193
194 **TE**

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

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

201
202 **Lena Sophie Thielmann**

203 Mhm.

204
205 **TE**

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

209
210 **Lena Sophie Thielmann**

211 Yes.

212

Group Part

213 **TE**

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

215

216 **Lena Sophie Thielmann**

217 Mhm.

218

219 **TE**

220 That's a bit abstract for me, I can't really put it into perspective.

221 What exactly do you mean by low demand for ecological technologies? Is that an issue?

222

223 **Lena Sophie Thielmann**

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

228

229 **TE**

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

231

232 **Lena Sophie Thielmann**

233 Mhm probably more of a communication issue then, right?

234

235 **TE**

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

238

239 **Lena Sophie Thielmann**

240 Yes.

241

242 **TE**

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

246

247 **Lena Sophie Thielmann**

248 That means that the problem for the circular economy is no longer so great because so much
249 is already happening.

250

251 **TE**

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

253

254 **Lena Sophie Thielmann**

255 Okay.

Group Part

256

257 **TE**

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

260

261 **Lena Sophie Thielmann**

262 Yes, that's definitely true.

263

264 **TE**

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

267

268 **Lena Sophie Thielmann**

269 This means that AI can be used for these different systems that need to be harmonized.

270 But also the different goals of the individual parties and this is probably the main point of
271 contact for AI to take on this structuring role.

272

273 **TE**

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

277

278 **Lena Sophie Thielmann**

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

281

282 **TE**

283 With pleasure.

284

285 **Lena Maria Pertz**

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

298

Group Part

299 **TE**

300 So the topic of sharing, do you have it in there somewhere? Yes, leasing subscription, but
301 also that you now say consumers use, for example, recyclable products from the outset, let's
302 say, and so in principle avoid consuming resources, do you know where that is included?
303

304 **Lena Maria Pertz**

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

311

312 **TE**

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

315

316 **Lena Maria Pertz**

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

332

333 **TE**

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

337

338 **Lena Maria Pertz**

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

Group Part

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

344

345 **TE**

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

349

350 **Lena Maria Pertz**

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

353

354 **TE**

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

358

359 **Lena Maria Pertz**

360 That is actually covered in point 6, I have that as a single point customer intelligence,
361 because I also read out a bit that in the circular economy, customer contact, co-creation is
362 very, very important, namely that, as you said, feedback can be used correctly by the
363 customer and that's exactly what I have now. Chatbots are virtual systems on the one hand,
364 but the sentiment analysts have also found analysis algorithms that allow feedback to arrive
365 directly at the right place, so to speak and not somehow collected somewhere and then the
366 feedback disappears, so to speak, which is immediately clear ok good, the feedback is
367 classified in such and such a way and sent here and there at the value chain point.

368 Exactly that would be point 6 then maybe we continue with point 2, any kind of service that
369 is offered during the product life cycle, so to speak, while the customer is using the product,
370 it is particularly important in the circular economy that certain services are offered in
371 relation to my maintenance and repair so that the life of the product is kept as long as
372 possible, so to speak, and I have found a lot about predictive maintenance I don't know if
373 you might have a point of view on that.

374

375 **TE**

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

Group Part

385

386 **Lena Maria Pertz**

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

389

390 **TE**

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

394

395 **Lena Maria Pertz**

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

400

401 **TE**

402 Well, I think many of these things have, you have complex ones.

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

407

408 **Lena Maria Pertz**

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

420

421 **TE**

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

425

426 **Lena Maria Pertz**

Group Part

427 Very good point. Yes, I will definitely include that. Exactly then the fourth point is leasing
428 and subscription and that is also very common in the B to B area, that devices are often
429 leased, that you can then simply send automatically, you already know that theoretically at
430 the beginning and then the subscription is over or this contract expires and then simply
431 notification is sent with, for example, new options for an extended extended leasing option,
432 that you then simply look at the economic aspect and try to generate a bit more revenue and
433 then suggest this to the customer based on such notifications and?
434

435 **TE**

436 So yes, I have the other, so what makes sense to me. This, if it's an end-of-rental
437 notification, not necessarily AI, but if what it says underneath is combined with analyzed
438 usage behavior and derives services from it or something, then it's back into AI.
439

440 **Lena Maria Pertz**

441 Yes, because what I have also noticed is that people often only look at all these AI use cases
442 to see how value can be captured/delivered. I've now tried to find out how it can be seen
443 economically, which of course is not necessarily the focus in the circular economy. But it
444 would be nice, I would also like to see a use case on how to support the AI approach in
445 relation to the revenue model, for example. Sharing Platforms, knowing that a certain
446 product or the resources is needed by one person which another one can offer, and because
447 of this complexity, AI can of course provide great support, cluster all the different
448 parameters and bring the certain actors together in an almost automated way, if the certain
449 data is of course there and also structured and prepared in such a way that it can be used
450 precisely.
451

452 **TE**

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

455 So according to the motto I don't know in principle, he needs the car and then it's as close to
456 me as possible, if I now have a car sharing example, because these things are always worse
457 in terms of service level than your own product, which you own and the more you need,
458 that's a big area of application for AI from my point of view. Sharing offering has just as
459 high a service level as your own, so it can't be exactly as high, but it comes as close as
460 possible to your own, if I own the sharing car exactly as close as I'm likely to need it as my
461 own, so to speak, and of course you can control that very strongly with AI.
462

463 **Lena Maria Pertz**

464 That's right, okay, I'll write it down perfectly and we've already talked about the last point.
465 Customer intelligence, can you think of anything else that AI could support, regardless of
466 the processes? In terms of process optimization in the value chain?
467

468 **TE**

Group Part

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

471

472 **Lena Maria Pertz**

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

475

476 **Annelie Sophie Steinbrenner**

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

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

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

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

487

488 **TE**

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

491

492 **Annelie Sophie Steinbrenner**

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

498

499 **TE**

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

503 I don't think that's the easiest thing to do, because I don't know to what extent it can be
504 modeled. But I think AI could at least help to understand or analyze something like that.
505 I can definitely imagine that AI could help with the second one. You're now in the area of
506 simulation or something from my point of view, right? That you say you somehow have a
507 kind of digital twin of a product and are now simulating - I don't know exactly what role AI
508 would play there, but it would certainly play a role - you are now somehow simulating a
509 hundred years of use in different scenarios by different types of users and so on.

Group Part

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

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

517

518 **Annelie Sophie Steinbrenner**

519 Yes, I understand that.

520

521 **TE**

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

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

528

529 **Annelie Sophie Steinbrenner**

530 No problem at all.

531

532 **TE**

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

535

536 **Annelie Sophie Steinbrenner**

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

541

542 **TE**

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

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

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

550

551 **Annelie Sophie Steinbrenner**

Group Part

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

555

556 **TE**

557 Exactly.

558

559 **Annelie Sophie Steinbrenner**

560 Well, I've already written down AI design approaches from other interviews and tried to
561 segment them into different phases.

562 The first thing that was mentioned more frequently is the pure design or pure layout of
563 products in the ideation or conceptualization phase. Trying to generate inspiration based on
564 past data.

565

566 **TE**

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

568

569 **Annelie Sophie Steinbrenner**

570 And then on the second topic, I've read a lot about material extraction and I'd like to ask you
571 about that again. You mentioned earlier with Lena Thielmann that material selection or
572 input materials should already be checked in order to ensure circularity in the end.

573 I would like to ask you again how exactly AI can help here or what your basic idea was?

574

575 **TE**

576 Materials all have to have a composition, especially when it comes to Co2 or recycling share
577 and precise dimensions. The properties are usually not available in a standardized form.

578 These are then some kind of data sheets or specifications. This is unstructured data, which
579 can be recognized very well with AI, let's say very strongly, automated and then made
580 comparable. Which would otherwise be a huge manual effort.

581

582 **Annelie Sophie Steinbrenner**

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

585

586 **TE**

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

591

592 **Annelie Sophie Steinbrenner**

Group Part

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

596

597 **TE**

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

602

603 **Annelie Sophie Steinbrenner**

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

606

607 **TE**

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

610

611 **Annelie Sophie Steinbrenner**

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

614

615 **TE**

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

618

619 **Annelie Sophie Steinbrenner**

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

621

622 **TE**

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

625

626 **Annelie Sophie Steinbrenner**

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

628

629 **TE**

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

635

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636 **Annelie Sophie Steinbrenner**

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

639

640 **TE**

641 No, nothing that comes to mind immediately.

642

643 **Annelie Sophie Steinbrenner**

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

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

649

650 **TE**

651 All right, thank you.

652

653 **Lena Sophie Thielmann**

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

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

659

660 **TE**

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

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

666

667 **Lena Sophie Thielmann**

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

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

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

673

674 **TE**

675 All right, great, then take care.

676

677 **Lena Sophie Thielmann**

678 Thank you ciao.

Group Part

679

680 **Lena Maria Pertz**

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

682

683 **TE**

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

1 **Appendix D5.** PdH's interview transcript

2

3 **Lena Sophie Thielmann**

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

6

7 **PdH**

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

10

11 **Lena Sophie Thielmann**

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

17

18 **PdH**

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

27

28 **Lena Sophie Thielmann**

29 Yeah, of course.

30

31 **PdH**

32 Yeah, somewhere there.

33 Yes, yes, yes, that's it.

34 And #2.

35

36 **Lena Sophie Thielmann**

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

41

42 **PdH**

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

Group Part

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

47
48 **Lena Sophie Thielmann**
49 So the stakeholders performance monitoring for the different collaboration partners is
50 different in the different contexts and sectors. For example, because cross sector
51 collaboration includes not only business to business collaboration but also business to
52 public, also with business to society, for example. So there is a lot of different performance
53 tracking options that you need to include.

54
55 **PdH**
56 Yeah. I think AI can play a role to basically contextualize performance information to
57 different audiences or different contexts. So yes, it could be. I think AI could be a little bit
58 more to the right, somewhere around there. Is it very important? Umm, no, I think it could
59 be a bit lower I feel, but yeah, it's a bit arbitrary.

60
61 **Lena Sophie Thielmann**
62 Because it is kind of an automatized process or why?

63
64 **PdH**
65 Why lower?

66
67 **Lena Sophie Thielmann**
68 Yes.

69
70 **PdH**
71 Well, because I think that, uh, circular economy initiatives. Of course, there are multiple
72 contexts, but uh, I mean a lot of practical examples around CE are also bipartisan. So two
73 companies working together, so then it's less of an issue I feel. So yeah, that's why I put it a
74 little bit lower. That was my thinking behind that.

75
76 **Lena Sophie Thielmann**
77 OK. Thank you. Then we have the risk of information loss, because today it's a bit unclear
78 on what kind of information needs to be shared and how is it stored.

79
80 **PdH**
81 Yeah, yeah, yeah. This is where I think especially generative AI can play a role to, assuming
82 it has access to the data, that you know people do not always know in advance which
83 information is relevant to other potential consumers of their waste products. So I think that
84 is also very hard to foresee. So I think AI can really, you know, be a sort of a broker where
85 it's looking proactively for information that is relevant for another company. And I think
86 actually it could be even higher if you ask me. Yeah, they're about.

87

88 **Lena Sophie Thielmann**

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

91

92 **PdH**

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

97

98 **Lena Sophie Thielmann**

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

101

102 **PdH**

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

106

107 **Lena Sophie Thielmann**

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

112

113 **PdH**

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

116

117 **Lena Sophie Thielmann**

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

121

122 **PdH**

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

125

126 **Lena Sophie Thielmann**

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

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

Group Part

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

173

174 **PdH**

175 What again is C-SC and CSCM?

176

177 **Lena Sophie Thielmann**

178 Cross sector collaboration and circular supply chain management.

179

180 **PdH**

181 OK. Yeah.

182 Yeah, I think this is actually where AI can play an important role.. That barrier could be
183 lowered by having AI offering a platform across sectors where you know there is a more
184 instead of adhoc 1-1 collaborations. Ideally, there would be sort of a structure across sectors
185 where you can find opportunities for collaboration in a more systemic manner.

186 Because without AI, the amount of information would quickly be overwhelming for
187 participants in such a platform. AI could help to personalize and and adapt the available
188 information and also suggests certain possible opportunities.

189

190 **Lena Sophie Thielmann**

191 Yeah, of course.

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

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

194

195 **PdH**

196 Yeah.

197

198 **Lena Maria Pertz**

199 Thank you, Lena. I will be the next Lena and I'll talk about the business model; the circular
200 business model and I quickly share my slides for that. So we can also have a look on what
201 I've researched so far. During my research I came across 5 main business models of circular
202 economy which you can basically see here in that value chain on the right. And I was
203 looking at the different processes that make value chain circular. So, for example, the reorg,
204 upcycling the remanufacturing, the reselling of already existing products or the service of
205 repairing and maintenance. And on the next slide, actually defined six of them, which you
206 can see on the left hand side of the slide. And I tried to already find some AI use cases for
207 these different types of processes of a circular business model and maybe we can go through
208 these different processes and through my ideas of AI use cases

209 And maybe you can validate them or give other opinions or ideas, or your perspective on
210 those. That's perfect, so maybe we start with the first, which would be the end of life. Take
211 back systems. So basically the process of getting a product of its end of use and collected,
212 transported back to the to the vendor and sort it like sort the different materials resources,

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

215

216 **PdH**

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

224

225 **Lena Maria Pertz**

226 Umm yeah, I think so too. And I think this is definitely discussed later with Annelie because
227 she's having the product design part. So that's why I'm looking only at the end of life.

228 So when the product was already designed, hopefully in a way that it can be.

229 Take back in the system basically. So this is already a good input, but maybe we can talk
230 about the ideas I had in turn in terms of the AI use use cases for this process, which would
231 be the route optimization. So basically the first two processes, so collecting and transporting
232 the actual product. So I could maybe have matching or clustering algorithms to find efficient
233 routes, get the A product as quickly and as environmental friendly as possible back to the
234 vendor.

235

236 **PdH**

237 You mean for? For demolition?

238

239 **Lena Maria Pertz**

240 Yeah, yeah.

241

242 **PdH**

243 The only new ones I would that makes sense, but you only knew once. Would bring in.

244 Is that who is to say that it is also the vendor that is going to take a part of the products?

245 Uh, because they may also be other facilities to do the to do the demolition or whatever you
246 call it. And the other Moodle for medication that may be useful there AI role is to.

247 Just to predict where certain waste materials will be needed by other manufacturers.

248 So that could be effective to take into account. So rather than, you know, bringing all, I don't
249 know, refrigerators to the same facility, maybe you can better bring them to the facility that
250 is already closer to the to the main uh to to the places where demand for for the outcoming
251 uh waste is is greatest if that makes sense.

252

253 **Lena Maria Pertz**

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

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256 and upgrades in a very regular time so that you keep the product as long as possible in one
257 life cycle. And for this one I have a pretty obvious AI use case, which would be the
258 predictive maintenance. So that you basically anticipate when a plant or any other kind of
259 equipment could have a potential failure in the next next time or schedule even maintenance
260 services before the actual product breaks down. And what is your opinion on that which you
261 agree? Or do you have any other use cases?
262

263 **PdH**

264 No, I I would agree. But I would even take it further. There are some early experiments
265 where you have equipment that own also apply that internally and they can change
266 sometimes the way they are operated.
267

268 **Lena Maria Pertz**

269 OK, so basically automated a little bit.
270

271 **PdH**

272 Yes, exactly.

273 And then adding to that another use case related to that is to have an AI chat bots or
274 something similar that assists the the the operator of the equipment in in in actually doing
275 the maintenance the you know that could be the replacement of a part or it could be
276 something else to to to do maintenance. But yeah, that could be another use case there.
277

278 **Lena Maria Pertz**

279 I actually found the use case of a chat bot in another process which I called customer
280 intelligence, because I read that the Co creation of the customer and the vendor if it's B2B or
281 B2C is very important in circular economies. So therefore also thought chatbots or any kind
282 of virtual assistant could be helpful in this way as well, because the feedback of the
283 customer could be directly get to the dedicated business function where the feedback should
284 be basically implemented. What is your opinion here?
285

286 **PdH**

287 Yeah, yeah, yeah. No, that makes sense. So having a more direct connection in essence
288 between the users and the designers of of a system, if that's what you're saying, yeah.
289

290 **Lena Maria Pertz**

291 Yes, correct. Yeah, that's definitely what I was saying.

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

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

301

302 **PdH**

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

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

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

308

309 **Lena Maria Pertz**

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

317

318 **PdH**

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

320

321 **Lena Maria Pertz**

322 Umm, correct. Yeah.

323

324 **PdH**

325 Yeah, yeah, that makes it that.

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

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

328 Yeah, that's all that.

329

330 **Lena Maria Pertz**

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

332 Thank you so much.

333

334 **PdH**

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

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

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

350

351 **Lena Maria Pertz**

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

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

355 Have a nice day.

356

357 **PdH**

358 You too.

359 Thank you. Bye.

360

361 **Lena Maria Pertz**

362 Thanks.

363 Bye, bye.

364

365 **Annelie Sophie Steinbrenner**

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

369

370 **PdH**

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

372

373 **Annelie Sophie Steinbrenner**

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

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

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

384

385 **PdH**

386 So I think as was mentioned by Lena number 2.

387 The use case that I just mentioned I think applies to what you mentioned in one of those
388 design strategies. I'm not entirely sure which one it relates to, but I guess it's about this
389 component optimization as I call it. Umm which is, you know, good for use. So that people
390 keep the product right. So they like it and they keep it. At the same time it balances that with
391 the extent to which the product can be remanufactured or taken apart and used for other
392 purposes.

393 Then another use case or use of AI in this context, for instance, could be in... Well, what I
394 found fascinating was the emotion. What did you call it? Emotional attractiveness of the
395 product or something like that.

396

397 **Annelie Sophie Steinbrenner**

398 Emotional durability, yes.

399

400 **PdH**

401 Yeah, yeah, yeah. So, here, perhaps AI together with other technologies could play a role in
402 the sense that depending on the product, you could perhaps use AI to offer more, let's say
403 personalization options like changing the color or changing the way the product looks or
404 feels.

405 And then perhaps by using AI you can make the product more flexible without replacing it.
406 So people can change the looks of the product. If they are bored with the former version
407 they can keep it more attractive for themselves. Uh, so that I think is one use case that came
408 to mind.

409

410 **Annelie Sophie Steinbrenner**

411 Yeah, that sounds good already. So maybe it makes sense to go one after the other through
412 the different design phases.

413 So, what I already found is that AI can definitely have a role in ideation and concept
414 development. So, for graphic inspirations, for instance. Do you see the role of how this can
415 also be applied, not for design in general, but specifically for circular design?

416

417 **PdH**

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

424

425 **Annelie Sophie Steinbrenner**

426 Yeah, makes sense makes total sense.

Group Part

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

430

431 **PdH**

432 Sure, sure. Yeah, absolutely, yeah.

433

434 **Annelie Sophie Steinbrenner**

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

437

438 **PdH**

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

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

455

456 **Annelie Sophie Steinbrenner**

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

460

461 **PdH**

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

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

Group Part

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

472

473 **Annelie Sophie Steinbrenner**

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

475

476 **PdH**

477 So that would be an example.

478 **Annelie Sophie Steinbrenner**

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

485

486 **PdH**

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

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

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

505

506 **Annelie Sophie Steinbrenner**

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

508 I think we're already over the time.

509

510 **PdH**

511 Alright, yeah.

Group Part

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

516
517 **PdH**
518 My pleasure.

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

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

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

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

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

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

1 **Appendix D6.** HK's interview transcript

2

3 **Lena Sophie Thielmann**

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

6

7 **HK**

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

11

12 **Lena Sophie Thielmann**

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

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

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

21

22 **HK**

23 Mhm.

24

25 **Lena Sophie Thielmann**

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

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

32

33 **HK**

34 With pleasure.

35

36 **Lena Sophie Thielmann**

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

42

43 **HK**

Group Part

44 Mhm.

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

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

50

51 **Lena Sophie Thielmann**

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

53

54 **HK**

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

59

60 **Lena Sophie Thielmann**

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

64

65 **HK**

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

74

75 **Lena Sophie Thielmann**

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

79

80 **HK**

81 I would. Also add to #2.

82

83 **Lena Sophie Thielmann**

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

87

88 **HK**

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

95

96 **Lena Sophie Thielmann**

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

100

101 **HK**

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

109

110 **Lena Sophie Thielmann**

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

114

115 **HK**

116 Mhm.

117

118 **Lena Sophie Thielmann**

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

121

122 **HK**

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

Group Part

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

131

132 **Lena Sophie Thielmann**

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

134

135 **HK**

136 Mhm. I would describe it as a mindset problem. Exactly the same as with sustainability.

137 For example, sustainability is not a circular economy and vice versa, so I think it's a mindset
138 issue, it's all very confusing for many people.

139

140 **Lena Sophie Thielmann**

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

148

149 **HK**

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

157

158 **Lena Sophie Thielmann**

159 Okay, yes, very interesting. Then we have approaches to risk management under point 8.

160 This simply means that the different parties involved in the collaboration have different
161 perceptions of risks and also perceive other issues as risks and react even more sensitively to
162 them accordingly.

163

164 **HK**

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

171

Group Part

172 **Lena Sophie Thielmann**

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

177

178 **HK**

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

184

185 **Lena Sophie Thielmann**

186 Yes.

187

188 **HK**

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

190

191 **Lena Sophie Thielmann**

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

195

196 **HK**

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

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

208

209 **Lena Sophie Thielmann**

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

211

212 **HK**

213 Very good. With pleasure.

214

Group Part

215 **Annelie Sophie Steinbrenner**

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

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

226

227 **HK**

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

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

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

240

241 **Annelie Sophie Steinbrenner**

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

246

247 **HK**

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

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

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

Group Part

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

260

261 **Annelie Sophie Steinbrenner**

262 Mmh.

263

264 **HK**

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

267

268 **Annelie Sophie Steinbrenner**

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

273

274 **HK**

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

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

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

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

285

286 **Annelie Sophie Steinbrenner**

287 Mhm.

288

289 **HK**

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

293

294 **Annelie Sophie Steinbrenner**

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

300

Group Part

301 **HK**

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

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

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

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

311

312 **Annelie Sophie Steinbrenner**

313 Mhm.

314

315 **HK**

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

318

319 **Annelie Sophie Steinbrenner**

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

325

326 **HK**

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

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

332 Design for refurbishment measures was refurbishment?

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

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

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

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

343

Group Part

344 **Annelie Sophie Steinbrenner**

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

348

349 **HK**

350 Mhm.

351

352 **Annelie Sophie Steinbrenner**

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

355

356 **HK**

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

359 Annelie Sophie Steinbrenner

360 Yes, yes, okay understood.

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

364

365 **HK**

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

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

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

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

375

376 **Annelie Sophie Steinbrenner**

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

379

380 **HK**

381 Great, I'm glad.

382

383 **Lena Maria Pertz**

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

Group Part

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

395

396 **HK**

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

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

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

407 I might see that in the step before.

408

409 **Lena Maria Pertz**

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

412

413 **HK**

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

416 Point 2 they have is about maintenance, repairs and upgrades and maximum user
417 friendliness.

418

419 **Lena Maria Pertz**

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

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

427

428 **HK**

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

Group Part

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

436

437 **Lena Maria Pertz**

438 Yes, definitely not, yes yes, that's quite funny to listen to.

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

443

444 **HK**

445 Yes, I'll find something maybe very briefly back the one because of chatbots.

446 Bots I also find that is also often related to the quality of products so I find chatbots so this
447 or circular products are extreme at the moment, so now for the end consumer, if you look
448 like that now. If you take a quick look at Consumer, for example, I think it's extremely high-
449 quality and extremely expensive and. I think I'm still on the track that I say, if I have
450 expensive products, then I want to have a real customer service and not a chatbot, but that's
451 just our culture or my view of things.

452 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
453 doesn't matter there again, so there's customer service.

454 Important, but not now, so it doesn't really matter in that respect.

455

456 **Lena Maria Pertz**

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

459

460 **HK**

461 Thirdly, optimal use of product by customer to training and consulting.

462 Mhm, productive analytics, transport, customizing. Yes me too.

463 But I see the point there too, I think. But although I see it, I would even see it very strongly,
464 because I think. As a business model, you can simply stay much closer to your customers
465 and much more. We are no more yes service sell than if you call in order cyclically or at
466 cyclical intervals again and again and say so bright how does it look?

467

468 **Lena Maria Pertz**

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

Group Part

472 In the circle economy, that you also involve the customer with you, that includes the
473 feedback and I think I also have a chatbot there, among other things.

474 But also the sentiment analysis, that you can include the feedback from the customer in the
475 following processes, so to speak, so that you can send the customer feedback directly
476 hopefully automatically with AI to the places where the business catch is also located, i.e.
477 where the feedback can be implemented directly, which is a bit part of point 3.

478

479 **HK**

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

481

482 **Lena Maria Pertz**

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

484

485 **HK**

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

491

492 **Lena Maria Pertz**

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

497

498 **HK**

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

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

503

504 **Lena Maria Pertz**

505 Ok, comparison portal, so to speak.

506

507 **HK**

508 Mhm Sharing platforms customers

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

510

511 **Lena Maria Pertz**

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

Group Part

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

Group Part

1 **Appendix E1.** Company A's interview transcript (AF)
2

3 **Annelie Sophie Steinbrenner**

4 Just before we start, I will introduce myself real quick. My name is Annelie Steinbrenner.
5 I'm originally from Germany. I study currently in my Masters in Portugal at Nova SBE and
6 I'm writing my master thesis now together with two other students. All of us are writing
7 together about how AI can accelerate the transition to a circular economy, and I personally
8 focus on one specific topic, namely the intersection between AI, circular economy and
9 product design. This is why I wanted to talk to you because I think the company you're
10 working for, I think it's called SXD, is the prime example of merging all of these mega
11 trends.

12 So that's exactly what I want to do now. I already prepared some slides as well, so that we
13 can dive into them later on as well.

14 But first of all, I would love to get to know you as well and maybe you can explain a little
15 bit of what your experience is and what you're doing for SXD.

16

17 **AF**

18 Ohh fair. I do a lot of things, so I'll keep those aside. I'll focus on the SXD part. It all started
19 with my thesis at Cambridge. So, I come from Bangladesh, which is a big manufacturing
20 hub for fashion and in my previous life I was a manufacturing engineer, industrial engineer
21 doing manufacturing work. And when I decided to do my thesis at Cambridge, I knew that I
22 wanted to focus on reducing carbon emission in the fashion industry. Coming from
23 Bangladesh fashion was a big emitter of carbon emissions, right. So, all these three things
24 combined, my background experience in manufacturing and fashion being one of the biggest
25 contributors to climate change and the third one is. Sorry, my bad. There's a third one. My
26 experience in manufacturing, fashion being one of the largest emitters and me coming from
27 Bangladesh. With all these three things combined, I decided to do my thesis on how to
28 reduce the impact of the fashion industry, specifically carbon impacts of the fashion
29 industry. And my focus was on how to manufacture these clothes more efficiently. Because
30 when you manufacture any T shirt or any clothing, you are throwing away on average 20%
31 of the fabric, 15 to 20% of the fabric is thrown away and the majority of the weights from
32 emissions come from the fabric itself. So, your transportation, your marketing, your
33 manufacturing, those are very minimal, but the fabric, the embedded carbon in the fabric is
34 quite huge. So, when you are throwing away 20% of the fabric, it's quite significant. So, my
35 thesis was on how we can manufacture clothing more efficiently.

36 At the same time, Shelly (founder and head designer of SXD), she did her MBA at Harvard
37 and at the same time we got connected because she wanted to launch her own zero waste
38 fashion brand. And she was looking for someone to manufacture it with. And there I was. I
39 was luckily stuck in Bangladesh due to COVID and she was trying to start her own brand
40 and we teamed up and we launched a few products together. So that's the initiation. And
41 once we started producing a few designs, we realized that it's...

42 So, Shelly designs her own zero waste products, right. And uh, the designs are, you know, if
43 you see a regular design of a T shirt or any clothing, they are like small pieces that you must
44 cut and throw away. So, her designs are more like a zigzag shape. If I can show you, hold
45 on. So, if you go to the climate refugee page. I'm trying to share my screen but let me see if I
46 can or cannot. I'm trying to figure it out, just bear with me.

47

48 **Annelie Sophie Steinbrenner**

49 Don't you worry. No rush.

Group Part

50 **AF**

51 Yeah, it's supposed to be here. Uh, but either way I'll probably send it to you after I find it.
52 Her designs are more like a jigsaw puzzle. If you have ever played with a jigsaw puzzle,
53 they're like very, you know, interlocked. And there is no gap in between so you are not
54 throwing anything away, right. And the issue that we ran into was now Shelly was using her
55 own brain and a lot of time to figure out this designs. So we thought that if we had to
56 scale... She was the bottleneck, right? She couldn't, you know, design full time. And even if
57 she did, we couldn't come up with a lot of designs, right? Because it's an iterative and time-
58 consuming process. And the iteration comes from, let's say you designed something for a 60
59 inches fabric width. But if the factory has 61 inches fabric width, then you must waste,
60 right? You must throw away that one inch fabric.

61 So this is where AI comes in. So, AI pops up these designs really quickly, so even if you
62 change the parameters like if you change it to 61 inches. If you want to change the sizes.
63 Right now, it's S size, M size, L size, you can automatically do it and it it's much faster using
64 AI. Previously, Shelly had to design for a S size T shirt, M size T shirt, L size T shirt.
65 They're all different. But in a regular T shirt, what happens is they're all the same designs.
66 You just enlarge it a bit, right? The same designs you just enlarge, we call it umm. Sorry
67 escaping my mind, but you get the idea right?
68

69 **Annelie Sophie Steinbrenner**

70 Yes, yes.

71

72 **AF**

73 You just endorse it. But in zero waste designs, every single design for every single size is
74 different because you're trying to fit everything in within that one fabric width. And this is
75 why we decided to focus on AI because of scalability.

76 And how our AI works is that we have, well it's not generative, it's more like a machine
77 learning tool. So, we train the model using previous datasets that Shelly had designed and
78 we also made up a lot of synthetic datasets because Shelly only came up with, let's say 15 to
79 20 datasets, right? But that's not nearly enough data to train a machine learning model. So,
80 we have to make up synthetic datasets to train the model that, hey, this is what you're
81 looking for and when the model was trained, it was able to pop up a lot of these designs.
82 So that's the AI part there, and the second AI part we are integrating is from Sketch to
83 design. So right now, if Shelly puts a sketch of a T shirt on her iPad, the AI can recognize
84 that it's a T shirt and then it will automatically create a pattern for a T shirt, right? So it's an
85 end to end solution.

86 Right now in a regular factory what happens is the designer will design something. Then
87 there are manufacturing people who figure out the pattern and then they'll figure out how to
88 manufacture it more efficiently. And there's a lot of waste because the manufacturing part
89 does not communicate with the designer. As a manufacturing person, I cannot go to H&M's
90 head of design and say that, hey, you need to change your design so that I can produce more
91 efficiently. I cannot do that, but here the designer can see what the pattern outcome is and
92 they can change their, you know, sketches to fit the more efficient outcome proposed by AI.
93 So you have an end to end view and that's a very good feedback loop that comes in to iterate
94 and help the designers to design more efficiently. So closing the loop between
95 manufacturing and designers.

96 So these are the two aspects. The first one is the zero waste patterning with different
97 parameters and the second one is sketch to patterns.
98

Group Part

99 **Annelie Sophie Steinbrenner**

100 OK, I see. That's very interesting. You've already told so much, but still I think I can come
101 up with my framework to get even more specific insights.

102 So what I found in my research is this framework about circular product design and maybe
103 we can go very quickly through it. So as you see on the left side, this is probably the end
104 goal that you design for a long use and either this is possible by designing for emotional
105 durability or by designing for physical durability. I think it's quite self explanatory. If you
106 have questions, please feel free to ask them. Then the second approach is to design for an
107 extended use, thereby designing for maintenance, designing for repair and designing for
108 upgrading.

109

110 **AF**

111 I know what you're talking about. It makes sense to me.

112

113 **Annelie Sophie Steinbrenner**

114 OK, perfect. So my question in the end is, can you see one of these areas as the one which
115 you and SXD is focusing on?

116

117 **AF**

118 So, um, the company vision that we started with is timeless designs. So for SXD, any design
119 that we make, any product that we develop, it is a timeless design. It's not fast fashion. We're
120 going for slow fashion, so any jacket that Shelly would design, it can be worn over the
121 years, like 10 years from now, 20 years from now. So, I feel like there is the element of long
122 use, so that is definitely embedded into the values of SXD and I can also go into the
123 extended use and the recovery.

124 So, if you look at a lot of our designs, they are straight cuts. So, what I mean by straight cuts
125 is like if you look at your T shirt, you know there is a cut that would be curved, that would
126 have edges. But a lot of the SXD designs are straight cuts, which means that if anything is
127 damaged, it's easy to sew. It's easy to manufacture, so time and resource efficient, but it's
128 also easy to repair, right? Any person without any sewing knowledge can easily do straight
129 stitches as opposed to someone doing a more complex stitch. So it's easily recoverable,
130 sorry, it's easily repairable. But, these are not major aspects.

131 Our major focus is on the long use. We want to make sure that the designs that we pump out,
132 the designs that we develop, they can be used by a person over the years, right? 30, 40, 50
133 years. And what we also make sure is that our designs do not need to be repaired. What I
134 mean by that is if we stitch something, we'll double stitch it and we'll do stress testing to
135 make sure that even if we try to rip apart, it won't rip. So all of our designs are stitched with
136 strong stitches that ensure that T-shirts or jackets won't tear. We double stitch here all the
137 vulnerable parts that are more likely to get torn So that kind of eliminates the need for
138 repairability, but also, even if the stitches do go off, it's very easy to repair because all our
139 stitches are straight lines.

140

141 **Annelie Sophie Steinbrenner**

142 OK, perfect.

143

144 **AF**

145 And the other thing is we do not design for remanufacturing or, you know recovering
146 because that's much more complicated and that design for fabric, it's more difficult.

147

Group Part

148 **Annelie Sophie Steinbrenner**

149 I see the point. OK, then I'm jumping once again in the AI aspect. So umm, you already
150 mentioned that you use AI to pop up with a lot of ideas. So, the ideation phase, I think is
151 definitely one part where AI could help. Additionally, what I read a lot is that AI is often
152 used for prototyping. Would you agree with that and can you elaborate a little bit on that?

153

154 **AF**

155 Yes, yes, absolutely. So for example, um, let's say Shelly has to come up with a design for a
156 T shirt, right? And she will tell the AI that we have right now: "Here's a sketch of a T shirt.
157 And here's the width of the fabric. Come up with a pattern for a T shirt right for this size, S
158 size or M size." So the algorithm will come up with one pattern right. Next, Shelly will try
159 to tell that, "OK, this is good, but come up with another one." So the AI will come up with
160 three or four designs. From that, Shelly will choose a few that is more adapted to our
161 manufacturability, right. For example, we tried to use a lot of waste fabric and when we use
162 waste fabric, it's difficult to control what kind of fabric we're getting. Sometimes it may be
163 61 inches fabrics, sometimes it may be like 65 inches fabric. We never know. So having this
164 AI here helps us to adapt to the changes.

165 So previously, Shelly designed something for 60 inch fabric which is a standard. And then it
166 turned out that uh we didn't find 60 inch fabric in the manufacturing, we just have 55 inches
167 right. Then Shelly had to go back to the design room and had to design it all over again. May
168 take weeks. May takes months. Who knows, right?

169 But now we can pop it up within like a few minutes. It's that simple, and it also gives us
170 plentiful options. That helps with prototyping, because now we have options to choose right.
171 And we have the options to choose which one is better, which one is more adaptable and
172 which one is easier to manufacture.

173

174 **Annelie Sophie Steinbrenner**

175 Yeah. OK. And can you go back to the idea of your working together with AI? Because
176 often there's the big fear of everyone that AI is going to eliminate designers in the end,
177 because designers are not anymore needed because AI is taking over the role. What do you
178 think of that? Are designers still needed in the future?

179

180 **AF**

181 Absolutely. So, I feel that it won't eliminate designers. It's basically enhancing the scalability
182 of the designers, right? So Shelly will always be needed. For example, the AI will generate a
183 lot of the designs right, but you still need a human experienced person to tell the AI that this
184 is feasible. But this is not feasible, right? The machine does not always understand what is
185 feasible in the real world. I mean eventually down the line, maybe with years of training it
186 will reach that stage. But for now I don't see it happening, at least in the next 10-15 years.

187

188 **Annelie Sophie Steinbrenner**

189 OK. Yeah, yeah, I understand.

190 And so, one more question. You said that fashion usually goes with trends and is very like
191 fast fashion oriented. So how do you deal with that? Because you said you do design for
192 long use, but how do you get the people to buy it? If it's maybe not really trendy anymore
193 and it wears out a little.

194

195 **AF**

196 You're absolutely right. That's why you have to target a niche, right?

Group Part

197 So I can give you an example of chairs, right. If you look at Herman Miller chairs, right, I
198 I'm pretty sure it's pretty famous in Germany. They have a higher price point and it's
199 associated with luxury. It's associated with a good brand. It's associated with durability,
200 right? So they come up with very simple designs. They are timeless designs. They're not,
201 you know, fleeting. They're not something that is a seasonal thing and still it is regarded as
202 one of the classiest things that you can have in your house because of the association with
203 luxury and timelessness.

204 So at SXD, we try to position ourselves as a more of a refined luxury brand as opposed to
205 something that is fast fashion, right. And there has been a lot of debate between Shelly and I
206 about should we make things more affordable because it can be used by more people or
207 should we keep it non disposable and at a higher price? Because if you can buy a T shirt for
208 \$5, you are more likely to throw it away, right? As Primark shows.

209
210 **Annelie Sophie Steinbrenner**

211 Definitely.

212
213 **AF**

214 As opposed to if you buy it for like \$50. You're like, hey, I want to have it for a longer time.
215 So there is always that debate. Are you making more impact by making it more affordable or
216 are you making less impact because people can't afford it? So there's always that fine
217 balance that you have to hit.

218
219 **Annelie Sophie Steinbrenner**

220 Umm OK. So that links right with my next question. So there's always this debate whether
221 circular economy is even realizable in terms of an economic sense or a business sense.
222 Because usually what a business wants is to be profitable. So how do you deal with this
223 issue of being profitable but also sustainable? Do you think these two can go hand in hand?

224
225 **AF**

226 No, absolutely. So I feel like we are in a niche that for example in a lot of places you'll see
227 sustainability is not profitable, right? You need to pump in more money to become more
228 sustainable.
229 You need to do more effort to become more sustainable. It's not profitable to be sustainable,
230 but in manufacturing it actually is more profitable to be sustainable because you are either
231 reducing waste, which cuts down your costs, or you are reusing waste, cutting down on your
232 material costs, or you are reducing processes by saving time and removing or reducing
233 manufacturing hours or our time for people. So there is this aligned business incentive,
234 specifically in the manufacturing domain and circularity which aligns with the business
235 objectives as well.

236 So I know from the broader sustainability field it's not everywhere, but in this particular
237 circular economy domain, it's very pronounced. There is a clear alignment between
238 profitability and sustainability as well, because if you can reduce waste, if you can reuse
239 waste, it's good for the business.

240
241 **Annelie Sophie Steinbrenner**

242 OK. I see. Yeah, that sounds reasonable.

243 So coming back to the framework which I showed you, just for me also for the upcoming
244 interviews and the entire thesis. As an expert, do you think these areas already cover the
245 major ideas of circular economy? Or do you think something essential is missing.

Group Part

246

247 **AF**

248 I think uh, you have hit all the three major domains, it definitely makes sense. When I saw
249 it, it was pretty obvious to me. It definitely makes sense.

250 Nothing at this time pops up as an answer to your previous questions, but I'll allude to a
251 personal anecdote I had. So when I was doing my thesis with the factories I wanted to show
252 them how they can reduce their waste, right? I wasn't going in with the objective that I
253 would save them money, I was just going into the objective that I'll save carbon emissions
254 right. And I thought it would be very difficult to sell because people are not interested in
255 saving carbon, but once they heard that by saving carbon emissions, you're basically saving
256 fabric and basically by saving fabric, you're saving money, they are more open to listening,
257 right?

258 And that is why I say that we are in a very unique domain where sustainability equals
259 profitability as well because you're saving waste and it's not, it's not the case everywhere
260 else. It's just a very specific domain here and you are at the center of it because you chose
261 circularity as your business thesis.

262

263 **Annelie Sophie Steinbrenner**

264 Yeah.

265 And just one last question. Uh, because it's just very interesting. Personally, not so much for
266 my thesis. How are you dealing, for instance, with shipping and your entire supply chain?
267 Because I feel like in the fashion industry, this is one of the major issues that, you know, like
268 a lot of fabric is manufactured in, for instance, Bangladesh. But then it's ordered in the US
269 or in Europe, so the shipping and everything in between is bad for the environment as well.
270 So how do you deal for SXD with this special problem? Or are you only shipping right now
271 within the US and manufacturing in the US?

272

273 **AF**

274 A very, very important question and it's a challenging one for a smaller company. So for us,
275 shipping is a big emitter of carbon because we are manufacturing in Bangladesh and because
276 we are still in a very small company. Sometimes we get orders of a hundred very small sizes
277 and for those sizes we cannot ship via the sea. We have to ship using the airplane. So it's
278 very carbon intensive, very expensive and we do recognize that. But uh, the challenge is we
279 cannot grow as a business if we don't make those sacrifices in the beginning. So if we are
280 not able to provide those hundred pieces, no one is going to give us the orders of 5000
281 pieces, 50,000 pieces or half a million pieces that we can ship by the sea. So it's a circular
282 problem. Again, like you cannot become sustainable without being unsustainable, at least for
283 the short term. So it's a short term loss that you're taking. But again, if you look at the sea
284 shipping, it's much more sustainable. It's very slow and the emissions from ship is much
285 lower than the airplane.

286

287 **Annelie Sophie Steinbrenner**

288 So it wouldn't make sense to, for instance, manufacture in the United States, right?

289

290 **AF**

291 It may take more carbon to, you know, manufacture in the states. Because maybe land is
292 more energy intensive here to, let's say, heat up. The factory is more energy intensive here
293 because there is like colder winters. So if you take all this into consideration, you may find
294 out that it's not the best way to manufacture in the US, in terms of carbon capture.

Group Part

295 For example, let's say uh growing bananas. Should we import bananas from South America
296 or should we grow bananas here in, in Canada or the United States, right? So people who
297 say that because you don't have to ship it, it's better to grow here. But if you consider like
298 how much more fertilizers it would take, how much more land it would take to grow the
299 same bananas here, it's not worth it. It's much better for the environment to ship it from
300 South America.

301 So there is a very good book. It's, I think global versus local that deals with these ideas. So
302 let me let me just Google it for you.

303

304 **Annelie Sophie Steinbrenner**

305 That's very nice. Thanks.

306

307 **AF**

308 Uh, I'll find the book and I'll send it to you. I read it in my grad school, so it dwelled on the
309 idea of should we always eat local or should we sometimes eat global? Because what's the
310 best approach? And the answer is you never know. So whatever is available locally, you do
311 use it, but sometimes it's better to use the global one because it's less carbon intensive.

312

313 **Annelie Sophie Steinbrenner**

314 Yeah, yeah, I see. No, that is very interesting. Such a cool topic, especially the fashion
315 industry.

316 Uh. I think that's actually it, because you already talked so much and let me know so many
317 great things.

318 So thank you again very much for your time and for all the insights.

319

320 **AF**

321 Ohh absolutely.

322

323 **Annelie Sophie Steinbrenner**

324 I think I can definitely use a lot of the things you mentioned in my thesis. So, if I do have
325 any questions left, is there the possibility to still reach out to you.

326

327 **AF**

328 Yes, of course. And even beyond that, if you go into my LinkedIn, if you see anyone else
329 you want to talk to, just let me know. I'm happy to introduce you.

330

331 **Annelie Sophie Steinbrenner**

332 That's great. Thank you so much. And it was a really, really nice interview.

333

334 **AF**

335 Yes. Thank you so much. I'm excited to see your thesis once it's published. Good luck.

336

337 **Annelie Sophie Steinbrenner**

338 Yes. Thank you again. Bye bye.

339

340 **AF**

341 Thank you.

Group Part

1 **Appendix E2.** Company B's interview transcript (RR)

2

3 **Annelie Sophie Steinbrenner**

4 So, everything is held in English. And I think we can start right away. What we are currently
5 doing is the following. I'm currently a master student at Nova SBE which is a Portuguese
6 Business School and I'm doing my master thesis. What I'm trying to find out is how AI can
7 be integrated into circular product sign. So basically I'm trying to get the essence of three
8 major topics: circular economy, artificial intelligence and product design. So that's it for the
9 moment.

10 I think you are a great expert in terms of artificial intelligence and product design, which is
11 why I wanted to talk to you. And without further ado I guess we can start off. Maybe you
12 can quickly introduce yourself?

13 Tell me where you're working, what your position is and also what key characteristics your
14 company has.

15

16 **RR**

17 So I'm working in the same sector for the past 23 years. This is my 24th year and my
18 objective is basically to ensure that whatever chips that are being produced are checked and
19 are without a bug before they go to the customer.

20 The process is the following: There is a design group. Then there is a manufacturing group,
21 and then finally it goes to the customer. So what happens is that when the chip is
22 manufactured and finally goes to the customer, we have to ensure that it is manufactured as
23 was expected. So I mean the chip is indeed manufactured as we expected, then we met the
24 expectation of the customer. So, there is a sync between the customer expectation and
25 manufactured chip.

26 Initially the customers' intention is given in the form of a document and then it is going to
27 be manufactured as a chip which has to replicate what the customer wants.

28 However, what happens if the chip does not behave as the customer wanted, then it goes into
29 what is called a "respin". That means the customer is not satisfied or the customer wants
30 corrections or there is some error which the customer wants to be checked.

31 The problem is though, once the chip is manufactured, nothing can be done about it
32 anymore.

33

34 **Annelie Sophie Steinbrenner**

35 Yes. Understood.

36

37 **RR**

38 So to repeat one of the points that you mentioned about the circular product design when
39 contacting me is an aspect that you mentioned about easy repair. Repair may not be always
40 possible in all kinds of semiconductor design, as it always involves considerable costs. So
41 once you manufactured a chip, it is not easy to repair it.

42

43 **Annelie Sophie Steinbrenner**

44 So it is or is not possible to use repair to keep the circuit circular?

45

46 **RR**

47 It is possible for a select. What I would say is, that select chips which are more expensive
48 could be repaired but it depends on the nature of the chip. In reality, most chips are not
49 being repaired. For example, if you have circuit for a car. So, for example, there is a chip

Group Part

50 which is controlling the braking. Now when the chip is controlling the braking, you don't
51 want it to fail or it can cause a life issue, right?

52

53 **Annelie Sophie Steinbrenner**

54 Yes.

55

56 **RR**

57 So what they do is they will add redundancies. So instead of a single chip, there could be 4
58 chips, so that even if one stops working, the other one will start, acting like a repair or a
59 backup mechanism.

60 So this is not really repair. So what you have is 4 chips and where one is going to act as a
61 backup for the other another.

62

63 **Annelie Sophie Steinbrenner**

64 So this brings me to the next question, does your company have any circular economy
65 related activities or are there any specific design characteristics you believe are crucial for
66 circularity?

67 Do you account for that in some way?

68

69 **RR**

70 Uh, we are working at more like, uh, the manufacturing side, right? I'm not sure if you are
71 aware that there are basically three major fabs in the world. One is TSMC, the other is Intel,
72 the other is Samsung. So all the major semiconductor chips are going to be out of these fabs.

73 So what happens is that there could be a chip A from TSMC and then there could be chip B
74 from TSMC. Now if there is a problem with chip A because of some physical
75 characteristics, we do not just want to correct chip A, but also we want to seek to correct

76 chip B which is already the chip of some other customer. So there is a company A which is
77 going to TSMC. There's a Company B which is going to TSMC. Now what we're trying to
78 see is, whether the learnings from company A can be carried over to Company B.

79

80 **Annelie Sophie Steinbrenner**

81 Understood. But what does that mean circularity wise? Do you account for circularity in
82 your design process?

83

84 **RR**

85 We do right? So for example, it could be the same company, saying company A, who will
86 have what is called a chip A0, A1, A2 etcetera. So what are mistakes that happen in A0? We
87 want to correct them in A1.

88

89 **Annelie Sophie Steinbrenner**

90 So basically what you're doing is you try to figure out the chip failures and how you can
91 remake the chips better the next time?

92

93 **RR**

94 Yes, that is correct.

95

96 **Annelie Sophie Steinbrenner**

97 Do you always start from scratch or are you using actually the chips from the beginning and
98 then maintaining them or remaking them, transforming them?

99

100 **RR**

101 Neither. So that is exactly where AI is coming into play because we do not want to rerun the
102 entire cycle, right? So what we are trying to see is whether we can avoid the design issues or
103 the physical issues which caused the repair or which is causing the defect without going to
104 the entire cycle, but by planning in advance for it based on previously generated data. So
105 what took, say, six months the last time, we try to reduce by, let's say one month and redo
106 the silicon again with the better performance and lesser error prone activity. The usually
107 man-manufactured defects are reduced and the processes accelerated.

108 Compared to actual manufacturing, engineering is changed as artificial intelligence is going
109 to be applied. And we will be ensuring all these ECO are applied so that the next revision of
110 the chip is going to be a much better chip quality wise and it is going to reduce all the errors
111 because they're in the previous version.

112 So what the companies usually do, they call it a dry run, is that A0 is not going to the
113 market. They'll just release A0 with samples and then once they see the problems, they will
114 try to fix it in A1 and then hopefully A1 will go to the market. If that also has an issue, then
115 they'll go to A2. In a perfect scenario, the A0 chip would ideally go to the market, but when
116 they see some issues, they go to A1.

117

118 **Annelie Sophie Steinbrenner**

119 Understood. So coming back to circular economy design principles, can you maybe mention
120 which circular design approaches are most important in your company?

121

122 **RR**

123 So if a chip is manufactured, it usually takes around six months, right? Six months. Hence,
124 you probably want to reduce all your iterations before at least six months. And you do not
125 want to halt your production as this would result in waste. Rather you want to ensure that
126 you correct your design before six months are over. Ideally you want A0 to go to full
127 production, but if you uncover or discover bugs later than six month, there is no way that the
128 design team can go ahead and you wasted a lot of resources and money. So what they will
129 say is that we cannot ship the chip. So instead of our delivery, which was expected in six
130 months, it will happen in only eight months or ten months later.

131 So we just stop with the actual manufacturing with real tangible products. So there is no
132 question of correction or the repair. It is going to be the change in the design itself which is
133 going to happen digitally. So we are not going to produce at all tangible products before we
134 know for a fact that the digital version has no bugs left.

135 Just remember that it is really expensive and a waste of resources if a chip is manufactured
136 with a bug in it. So, the later in the design and manufacturing process you will uncover or
137 discover a bug, the worse it is. And the more expensive that entire process is going to be.

138 This is exactly why you need digital prototyping before starting the tangible manufacturing.

139 So what we are doing is called an NRE. It is a nonrecurring engineering cost. So for
140 example, Apple has just now released one public statement that their latest chip is going to
141 involve at least \$1 billion. The designing of the chip itself is going to take \$1 billion, so if
142 they make a mistake, then you can imagine what will be the engineering cost. And then
143 finally, what will be the cost of the chip that is going to come out in a tangible form?

144

145 **Annelie Sophie Steinbrenner**

146 So basically, what you're trying to do is to, um, try to save money but also to reduce waste in
147 the manufacturing process, right?

Group Part

148

149 **RR**

150 Yes. Another point is that there is a drastic reduction in resources from A0 to A1. So if A0
151 requires 400 people or 500 people, A1 is expected to require 1/4 that is 25% less of the
152 workforce.

153

154 **Annelie Sophie Steinbrenner**

155 What about material?

156

157 **RR**

158 This is the learning is done for the same material and the same subprocess cycle only
159 because every time you change your process, the learning may not be applicable for the new
160 process.

161

162 **Annelie Sophie Steinbrenner**

163 Can you please clarify once again, where exactly do you leverage AI in product design? Is it
164 correct that you can identify bottlenecks and reduce iterations in the design process and
165 therefore you can reduce design cycle time.

166

167 **RR**

168 Yes. It is actually more about the resources rather than time. From the point when you do the
169 next iteration, the number of resources that we need in terms of, whether it's people, a tool,
170 machines, can be cut down by at least 1/4, 25%.

171 In the first chip it will not be possible to avoid all iterations, but definitely in the second chip
172 Generally, we want to avoid bigger iterations as much as possible, so the feedback has to
173 ensure that whatever mistakes that we made in the earlier cycles, we note it down and we see
174 that those mistakes are not repeated in the next chip. When you see a feedback, what we do
175 is we first check whether errors that happened in the previous version is happening for the
176 first time or not. We do not check for the entire step. You only check for the howlers, so to
177 say. So which were the issues that were causing problems in the previous chip? Now, are
178 these errors reappearing? Ideally they should not. So if they do not, then that means we have
179 fixed the issue. That means we have learned from the previous mistakes through data. Now
180 we are doing our job. Our process is much better and effective because we are handling
181 those iterations without facing those issues ever again.

182 In other words we use AI and ML to encode all the mistakes that happened so they will
183 never happen again.

184

185 **Annelie Sophie Steinbrenner**

186 So you use collect and analyze huge amounts of data using AI. And consequently you test
187 and prototype digital chips accounting for learnings from the data by using AI again?

188

189 **RR**

190 Yes, yes, describing, testing and prototyping, that is how we can reduce the iteration. We
191 want to ensure that your iteration time itself comes down, so every step has to be meaningful
192 and should not entail an error. Whatever the mistakes that we did the last time, we should
193 not do them again. That is the basic idea.

194

195 **Annelie Sophie Steinbrenner**

Group Part

196 I just want to clarify one last time. What you mentioned is basically you're not doing
197 anything with recycling or recovery, right? Rather you are trying to design for a long use by
198 ensuring physical durability without any need for extending the use or recovering parts by
199 e.g. remanufacturing the product?

200

201 **RR**

202 Yes. This is important. We design so that we should not need to remanufacture anything.
203 We should not even start manufacture if it is error prone and we think we would need to
204 remanufacture, repair, etc anytime in the future, right?

205 Silicon first silicon pass. That means you should not manufacture unless you are very sure
206 that it will work. So then we should not manufacture silicon and then find that it is buggy or
207 it is not working as per the customer expectation. We have to ensure that whatever silicon
208 comes out has a specific quality. This is called the first pass silicon.

209

210 **Annelie Sophie Steinbrenner**

211 What is your ultimate goal when you design a chip? That it's used rather long or that it can
212 be recovered?

213

214 **RR**

215 For whatever product that we come up with when we design, we want to ensure that it suits
216 the customers' expectations. The intent is basically in some sort only an idea. In the future,
217 the ideas is going to be a tangible piece of chip and it should work exactly as per the
218 expectation of the customer.

219 So this idea of the chip should be a perfect translation of the idea. Therefore all the intent
220 needs to be captured correctly. Once it has been coded correctly, has it been tested correctly,
221 then finally manufactured correctly and then it goes to the customer and fitted correctly.

222

223 **Annelie Sophie Steinbrenner**

224 So in other words, your goal is to have a long use of the chip by ensuring that you only
225 manufacture chips which are tested and prototyped correctly?

226

227 **RR**

228 So we call it correct by construct. That is the idea. We should not manufacture any chip
229 which is supposed to be defect. We cannot manufacture unless we are 100% sure. It is all
230 about better reliability of the chip.

231

232 **Annelie Sophie Steinbrenner**

233 Now slowly coming to the last question: As an AI expert, where do you think lies the
234 biggest potential for AI in terms of helping with circularity in product design?

235

236 **RR**

237 My company wants to ensure that whatever learning is done by the first company, we learn
238 from it and if there are mistakes or if there are bottlenecks, if there are any hurdles that they
239 face, the next company should not do the same mistakes again. First of all, we understand
240 what those bottlenecks are, and then the next company that we get as our customer should
241 not redo the same problem. So we charge our next customer saying that we will avoid all
242 those iterations. So if the first customer took 12 months, we assure that the next customer
243 should take only nine months for the same process. So that is our gap. That is our guarantee.

Group Part

244 The businesses will not cooperate to share their findings. We have to cooperate the various
245 information, that is our USP. For example, although companies use the same fab, company
246 A will not know that Company B manufactured in the same fab, but we know.

247
248 **Annelie Sophie Steinbrenner**

249 So coming back to the main research question, how can AI be integrated in circular product
250 design?

251 What would you say in terms of your understanding from the semiconductor industry?

252

253 **RR**

254 The main problem is the ecosystem. Whatever issues one company faces, they should be
255 visible across the ecosystem for other companies as well, so that they'll not repeat the same
256 mistake.

257 So if there is an automobile company A, and then there's another automotive company B.

258 Now there is no point in A and B repeating the same mistake. The companies will not be
259 willing to disclose their learnings as they are profit driven.

260

261 **Annelie Sophie Steinbrenner**

262 Yah, but you still see the potential for AI to bridge that gap, right?

263

264 **RR**

265 Yes, most definitely. Company A, which did the mistake can ensure that it does not repeat
266 the same mistake itself, but it will not tell Company B. Here is where AI and third-party
267 companies come into place as they have all the knowledge to reduce mistakes and calculate
268 optimal designs.

269

270 **Annelie Sophie Steinbrenner**

271 Okay cool. I think that helped a lot. It was definitely very interesting and complex. I learned
272 a lot for sure. So thank you so much for your time. Once again. I think I can definitely use
273 quite a bit for my thesis.

274

275 **RR**

276 Okay.

277

278 **Annelie Sophie Steinbrenner**

279 Do you have any more questions left?

280

281 **RR**

282 Is this a sponsored research or is it an educational research only? Or is it like sponsored by
283 some company who wants to know these detail?

284

285 **Annelie Sophie Steinbrenner**

286 No, no, no. It's actually just educational. So it's academic driven, it's for my master thesis,
287 but I'm not writing together with a company. I'm trying to get a lot of insights from different
288 industries in order to understand what AI can do for product design across different
289 industries and to figure out whether there's a major trend.

290 **RR**

291 Okay.

292

Group Part

293 **Annelie Sophie Steinbrenner**

294 Okay. So if you do not have anymore questions, I would like to thank you once again.

295

296 **RR**

297 Thanks a lot and have a nice day.

298

299 **Annelie Sophie Steinbrenner**

300 Have a nice day. Bye, bye.

1 **Appendix E3.** Company C's interview transcript (DW)

2
3 **Annelie Sophie Steinbrenner**

4 Alright, the transcription should work now. First, I'll introduce myself again and tell you
5 what I'm currently doing and what I'm trying to find out with this study. I'm Annelie and I'm
6 currently studying for my Master's degree at NOVA in Lisbon. I'm currently writing my
7 Master's thesis in the field of Circular Economy and Artificial Intelligence. Or rather, I'm
8 writing my thesis with two fellow students. Within this field, I am specializing in product
9 design and how AI can improve the design of circular products. Therefore, I am currently
10 looking for experts in the field of AI, circular economy and also product designers. Since
11 you are a product designer and I am very interested in it and otherwise have few points of
12 contact with the field, I am very much looking forward to our interview.

13 Well, I think that's it for now. Could you maybe introduce yourself to me again and tell me a
14 bit about your background, how many years of experience you have, where you work and a
15 few other interesting things you would like to share?

16
17 **DW**

18 Of course, my name is [REDACTED] and I studied Design & Product Management. Since 2017, I
19 have been able to gain experience at several brands in the automotive industry. My core
20 competence lies in design.

21
22 **Annelie Sophie Steinbrenner**

23 I'm totally happy to interview a product designer for once and think you can give me some
24 interesting insights either way.

25 I have prepared a few slides to go through the topic more quickly. Maybe I can just share
26 them quickly. Hang on. Can you see my screen?

27
28 **DW**

29 Yes, I can see it.

30
31 **Annelie Sophie Steinbrenner**

32 Okay. Great. So what you see here is a framework. I took it from the literature. It describes 8
33 design approaches for maintaining the circularity of products. Basically, there are three
34 goals that a product designer should take to heart and work towards. Either design for long
35 use, which includes building an emotional connection. This means that the customer is not
36 only interested in the technical capability of products, but also in establishing a relationship
37 and emotions with the product. And secondly, that a product has reliability and durability.
38 For example, a very long warranty. As you can see in the middle, the aim can also be to
39 design for extended use. This is possible if you make maintenance, repair and upgrading
40 easily accessible. The aim here is actually to return the product to its original function. I
41 think that is more or less self-explanatory. Ultimately, however, you can also aim for
42 recovery and change the product a little through recontextualization, or however you
43 pronounce it, refurbishment or remanufacturing, so that it can still be used in a slightly
44 modified form.

45 My question to you now would be theoretical, so you don't have to talk explicitly about your
46 work or company... Theoretically speaking: Which of these design approaches are used in
47 the automotive industry? Or what is your goal as a designer? Do you want to design for long
48 use, extended use, or recovery?

Group Part

50 **DW**

51 We clearly want to design for long use. On the one hand, of course, because of the
52 company's image and name for physical durability. To satisfy the customers. On the other
53 hand, especially in the motorcycle sector, also for emotional durability. Motorcycles are
54 simply a leisure hobby and not just a means of transportation. They are fun and therefore
55 also have emotional value for customers.

56 Maintenance is also an important factor in the automotive industry in general. Maintenance
57 is extremely necessary, as individual parts have to be replaced from time to time. After all, it
58 is simply an object of daily use and something might wear out. You can see this in all the
59 repair shops that exist in the automotive industry and also by the fact that spare parts are
60 produced and kept in stock. In this respect, extended use is also highly relevant. If I think
61 about it again, maintenance is in the automotive industry as a part of extended use the most
62 important design strategy, even more than design for long use.

63

64 **Annelie Sophie Steinbrenner**

65 That's interesting. So to summarize, you're saying that emotional durability is particularly
66 important due to the leisure factor, but maintenance is also simply deeply rooted and you
67 pay attention to this as a product designer?

68

69 **DW**

70 For recovery. In a normal Automotive World with combustion engines, that wasn't much of
71 a topic because the average sentiment is that there's an established market for vehicle
72 recycling worldwide and that it's not so much.

73 That's the case of misaligned stakeholder interest. The automotive industry doesn't care so
74 much about circularity. The car, once they earned the money with the maintenance of the
75 product, they don't care which recycling company gets the product at the end. So, there is
76 not much alignment, and also they don't care how they can disassemble the car later. So,
77 what very often happens is sections and components are glued instead of screwed. So, you
78 have basically no chance to take them apart because it's 30 cents cheaper per product. That
79 means the recovery bit in the old world is not so important for the automotive industry.

80 But now in the battery electric world, it becomes more interesting in the sense of resource
81 security. So, what do we do with the old batteries? It's not recontextualization or
82 refurbishment? It's probably recycling, right?

83

84 **Annelie Sophie Steinbrenner**

85 OK, I see perfect.

86

87 **DW**

88 Yeah, because recycling is in EVs a bigger market than the recontextualization market in
89 normal cars, because the second life battery thing doesn't really work. So most of the car
90 industry is focusing on actually shredding them and using the materials again rather than
91 actually doing that. What is interesting for certain car parts is the design for
92 remanufacturing.

93 There's ZF, for instance, they do refurbish transmission gearboxes, which is interesting. And
94 also, for other industries, like big machinery and stuff remanufacturing is a bigger topic.
95 If you investigate consumer goods, it's different. When you think about reuse of certain
96 materials, for instance. That's a different story there.

Group Part

97

98 **Annelie Sophie Steinbrenner**

99 And now, to complete the topic, the question about AI. Where do you see the opportunity
100 for AI to improve or accelerate the design process in one of these design approaches?

101

102 **DW**

103 Do you mean design in general now or do you mean AI in relation to Circularity?

104

105 **Annelie Sophie Steinbrenner**

106 No, I mean in relation to Circular Product Design.

107

108 **DW**

109 Hmm. That's difficult... In general, I would have said that AI has the most chance to help in
110 the ideation phase, at the very beginning of the design process. Due to huge amounts of data
111 and sheer quantity, AI can simply make things clearer and help the product designer to
112 create and break down a few ideas. In the ideation phase, I think there is the biggest
113 potential for AI and AI can support the designer e.g. to find inspiration. However, this is
114 always the case and not specific to circular product design or the automotive industry.

115

116 **Annelie Sophie Steinbrenner**

117 To come back to what you said before. You said you know about surface design and
118 materials and coatings and stuff... Do you think AI could also help in these areas. For
119 example, to test formulas. Or I've also often read that AI can help to check toxicity and
120 exclude materials? Do you think that's also possible?

121

122 **DW**

123 I don't know exactly. It would of course be a help if AI could provide a better overview of
124 the countless materials and their properties. In other words, it would offer realistic
125 suggestions for each component and its requirements. That would save a lot of time and
126 provide a great basis for discussion.

127

128 **Annelie Sophie Steinbrenner**

129 As you mentioned earlier, you are also trying to design for Emotional Durability. So, you
130 have to know your customers well and be able to assess what they want. Because, as we all
131 know, the customer is king. I once brainstormed. Do you think that AI could also be used to
132 capture consumer behavior as data and then design products specifically for these consumer
133 preferences?

134

135 **DW**

136 Collecting and classifying the data that already exists certainly works well, but in the early
137 phase of a product we are trying to serve the customer of the future, so to speak. And it's
138 about having personal empathy and knowledge of human nature in order to be able to assess
139 your customers and design what will ultimately appeal to them. AI still lacks that at the
140 moment. Creativity itself is also super important. Let's see what that looks like in the future
141 and whether AI will be able to do that at some point...

142

143 **Annelie Sophie Steinbrenner**

Group Part

144 Apart from that, I've also read in some papers that AI is being used for testing and
145 prototyping. I can imagine that what used to be necessary to test products tangibly is now
146 much easier to simulate using AI. What do you think?

147

148 **DW**

149 To briefly explain the design process. At the beginning there are sketches, which are then
150 converted into a 3D model, this is then transferred into a physical model for testing, and the
151 result is then transferred back into a digital 3D model and so on. For years, companies have
152 been trying to make this process completely digital. In other words, replacing the physical
153 model with a digital one. So far, however, it has never really worked. With a physical 1:1
154 model, the quality of the surfaces and proportions is still better than with purely digital
155 models. Maybe we'll get there one day, but unfortunately not yet. Nevertheless, it is already
156 the case that many steps in prototyping have already been digitized, but not yet completely.
157 Let's see what AI can do in the coming years. But I am very optimistic that AI can really
158 help in predicting maintenance or when a product needs repair.

159

160 **Annelie Sophie Steinbrenner**

161 You also said earlier that designers could get a lot of help from AI in the ideation phase.
162 Don't you think that there is also the danger or problem that people could lose their jobs?

163

164 **DW**

165 People are quick to deny AI's competence in any creative work. But perhaps I'm too gullible
166 and can't yet estimate how good AI can really become in the future. I think individual jobs
167 will disappear like everywhere else, but there will still have to be product designers. At the
168 moment, I still see AI as a supporting tool to make the design process more efficient and
169 comprehensive.

170

171 **Annelie Sophie Steinbrenner**

172 Do you see any other dangers of AI or Circular Economy?

173

174 **DW**

175 Not necessarily a danger. But I believe that it is often simply difficult to really bring circular
176 economy and economic thinking together in the real world. Although circularity is an
177 increasingly important word and companies are trying to become more sustainable, the fact
178 is that companies still have to remain economically viable, not least in order to keep up with
179 the competition and ultimately survive. Of course, I was even more idealistic during my
180 studies, but I quickly realized that in real working life, profitability is the basis of everything
181 in a company. Ultimately, it would of course be most sustainable if a product is as durable as
182 possible. However, this in turn has a negative impact on factors such as manufacturing costs
183 or the degree of innovation in a product. You want to offer new developments as quickly as
184 possible and customers also want to own a modern, contemporary product. So there is a
185 trade-off on both sides between longevity and progress.

186

187 **Annelie Sophie Steinbrenner**

188 What you just said contradicts a bit what you said earlier, namely that you guys design for
189 long use. I have another example of long use to illustrate this. Saddleback's example is taken
190 from the literature. You can also see a photo here on the slide. These are leather bags in the
191 "old-fashioned" style. Or let's say vintage. This is a product that does not break quickly due
192 to the good leather. In addition, the product has a very long guarantee and does not adapt to

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193 the latest fashion trends. That's different in the transportation industry. I mean, a motorcycle
194 doesn't last forever. Maybe 15 years if it runs well? And there's also a lot of wear and tear.
195 And you always keep up with new trends. Sure, there are a few old-timers, but basically
196 you're always manufacturing new products in order to be progressive and profitable. I guess
197 it's rare for a motorcycle to be passed down from father to son or daughter?

198
199 **DW**

200 I wouldn't agree with you on everything. You can't say that in general terms either... My
201 father, for example, still has his motorcycle, which he rode as a teenager. It's probably over
202 35 years old now. And he still rides it. As already mentioned, a motorcycle is not just a
203 means of transportation like a car and is therefore not ridden quite as much and wears out as
204 quickly. But of course there is also the other extreme. Of course, there are also riders who
205 ride on the racetrack and really push and wear out their motorcycles. Of course, these bikes
206 don't last as long.

207
208 **Annelie Sophie Steinbrenner**

209 So you would say that it doesn't just depend on the industry or the brand which design
210 approach is used, but also on the individual use cases.

211
212 **DW**

213 Yes, absolutely! Some motorcycles are designed for different purposes than others.

214
215 **Annelie Sophie Steinbrenner**

216 That's all interesting. I guess to come back to the framework, I have one last question: Can
217 you think of anything else that might be missing from this framework as a design approach
218 apart from recycling? Or anything else in general that you can think of and would like to
219 share?

220
221 **DW**

222 I don't think so... I think recycling is still an important point. And in general, the question we
223 mentioned earlier about the extent to which circular product design and profitability can be
224 ideally combined.

225
226 **Annelie Sophie Steinbrenner**

227 Thank you very much. This is all really exciting. I think I've already got the most important
228 information. So I'm going to stop transcribing now.

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