Leveraging AI for sustainability in the fashion industry: anticipated and unanticipated consequences

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Abstract – English

In the context of sustainable development, the fashion industry faces the challenge of aligning its practices with environmental and ethical standards. This thesis explores the potential of Artificial Intelligence as a transformative tool for achieving sustainability in this sector. The research focuses primarily on understanding how AI can contribute to sustainable fashion, while critically examining the unintended consequences of AI implementation. This exploration is based on two key research questions: 'What consequences, challenges, or risks may arise from the application of AI in the context of sustainable fashion?' and 'How can we use existing AI tools and technologies more responsibly?'. It applies a qualitative research approach, conducting an in-depth analysis of interviews with industry experts, coupled with a comprehensive review of relevant literature. The findings highlight the dual role of AI in sustainable fashion. While it can bring significant benefits in terms of reducing textile waste and increasing supply chain transparency, it also poses challenges that require careful consideration. The research concludes that a balanced approach is needed to successfully integrate AI sustainably, taking into account both its benefits and potential drawbacks. This thesis contributes to a better understanding of the role of digital technology in sustainable fashion by providing a nuanced perspective on the impact of AI and guiding principles for its responsible application in the industry.

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Abstract – Portuguese

No contexto do desenvolvimento sustentável, a indústria da moda enfrenta o desafio de alinhar as suas práticas com padrões ambientais e éticos. Esta tese explora o potencial da Inteligência Artificial como uma ferramenta transformadora para alcançar a sustentabilidade neste sector. A investigação centra-se principalmente na compreensão do modo como a IA pode contribuir para a moda sustentável, ao mesmo tempo que examina criticamente as consequências não intencionais da implementação da IA. Esta exploração baseia-se em duas questões de pesquisa principais: 'Que consequências, desafios ou riscos podem advir da aplicação da IA no contexto da moda sustentável?' e 'Como podemos utilizar os instrumentos e tecnologias de IA existentes de forma mais responsável?'. Aplica uma abordagem qualitativa, realizando uma análise aprofundada de entrevistas com especialistas do sector, juntamente com uma análise exaustiva da literatura relevante. Os resultados destacam o duplo papel da IA na moda sustentável. Embora possa trazer benefícios significativos em termos de redução dos resíduos têxteis e de aumento da transparência da cadeia de abastecimento, também coloca desafios que exigem uma análise cuidadosa. A investigação conclui que é necessária aplicar uma abordagem equilibrada para integrar com sucesso a IA sustentavelmente, tendo em conta tanto os seus benefícios como os seus potenciais malefícios. Esta tese contribui para uma melhor compreensão do papel da tecnologia digital na moda sustentável, fornecendo uma perspetiva diferenciada sobre o impacto da IA e princípios orientadores para a sua aplicação responsável no sector.

Título: Alavancar a IA para a sustentabilidade na indústria da moda: consequências antecipadas e imprevistas.

Autor: Maja Peric

Palavras-chave: Sustentabilidade, Desenvolvimento Sustentável, Inteligência Artificial, Tecnologias Digitais, Moda Sustentável

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List of Abbreviations

AI	Artificial Intelligence
EU	European Union
Gen AI	Generative artificial intelligence
GHG	Greenhouse Gas
GM	Gioia Method
GPT	Generative Pretrained Transformer
LLMs	Large Language Models
SDGs	Sustainable Development Goals

1. Introduction

1.1 Problem Statement

In the constantly changing fashion industry, the convergence of Artificial Intelligence (AI) and sustainability has become a prominent area of research and development in the past years (McKinsey & Company, 2023; Milton, 2023; Wren, 2022). As the industry faces environmental, social, and economic challenges, the integration of digital technologies offers the potential for transformative outcomes. According to McKinsey & Company (2022), the fashion industry remains one of the most ecologically unsustainable sectors, emitting around 2.1 billion tons of CO_2 per annum, representing 4% of global emissions. Additionally, 85% of textiles are either sent to landfills or incinerated, despite the potential for many of these materials to be reused (McKinsey & Company, 2022). Further, the EU Strategy for Sustainable Textiles is adopting various regulations and directives that impact the entire fashion value chain (McKinsey & Company & Business of Fashion, 2023). Regulations range from extending the producer's responsibility to requirements of reporting on social and environmental activities using standardized methodologies. Other proposed regulations include bans on the destruction of goods and the shipment of waste to the Global South (McKinsey & Company & Business of Fashion, 2023). Digital technologies, including AI, hold promise for assisting with decarbonization efforts, reducing energy consumption, and promoting the transition to renewable energy, thus advancing sustainability, and contributing to the attainment of the Sustainable Development Goals (World Economic Forum, 2022). AI, with its ability for advanced data analytics and machine learning, presents unparalleled opportunities to tackle these challenges. The size of the fashion industry with its dynamic nature and above-average availability of data, makes this industry especially suitable and interesting for big data analytical tools such as AI (Dekimpe, 2020). However, the integration of AI into sustainable fashion practices is not without its complexities. While AI can transform the business and significantly improve environmental performance, it can also have a negative influence if not managed correctly. Information ethics issues such as data privacy, cyber security, and digital violence (Hearn et al., 2023) are only some of the threats of implementing AI into businesses. While improved forecasting, sustainable supply chain management, and facilitated second-hand shopping are desirable outcomes (Rever, 2023; Milton, 2023; Sanvt Journal, 2023; Raidl, 2022) , the unintended consequences of AI raise critical questions concerning privacy, legal boundaries, and ethical implications (McKinsey & Company, 2023; Bondarenko et al., 2022; Möller, 2020). Although the literature is focused on the promises of AI for improved productivity and efficiency (Abdul-Hamid et al., 2021; Bilgram & Laarmann, 2023), enhanced innovation (Haftor & Climent, 2021), and sustainable development (Vinuesa et al., 2020; Jean et al., 2016; Keramitsoglou et al., 2006), limited attention has been given to the potential negative effects, even less to the second-order unintended consequences for society and environment. Two European programs are further highlighting the relevance of this research: The European Green Deal (European Council, 2023), focusing on a plan for achieving climate neutrality in the EU by 2050, and the EU Digital Decade (European Commission, 2023), empowering advancements toward a digitally sovereign and competitive EU with a focus on digital skills, infrastructure, business digitization, and the use of AI. This alignment of environmental and digital strategies highlights Europe's dedication to a secure, safe, and sustainable digital transformation, which coincides with the objectives of this study. This study endeavors to offer valuable insights for organizations looking to responsibly use AI in the pursuit of sustainable fashion practices by concentrating not only on intended effects but also on unforeseeable consequences. This emphasizes the contribution of this research not only to the literature, but also to practice and policy.

1.2 Research objective

The main objective of this study is to provide a comprehensive evaluation of the potential positive and negative impacts of AI deployment within the sustainable fashion industry. This research is particularly significant due to the limited scholarly focus on the possible negative impacts and unintended second-order consequences of AI on society and the environment. The aim is to outline effective strategies for the responsible use of already-existing AI tools and technologies. This research seeks to address a crucial gap in modern literature while providing practical insights for industry professionals and informing policy decisions. This study has both academic and practical importance, as it aligns with the European Union's strategic objectives under the European Green Deal and the EU Digital Decade.

1.3 Research questions

Therefore, it is crucial to point out the unintended consequences, as this field seems rather less focused on in recent research. Two guiding research questions were developed to further advance research in this area:

1. What consequences, challenges, or risks may arise from the application of AI in the context of sustainable fashion?
2. How can we use existing AI tools and technologies more responsibly?

1.4 Thesis outline

The thesis comprises five sections. The first section is the Introduction, which states the research objectives. The second section presents the Literature Review, encompassing concepts and components based on the existing literature. In the third section, the Methodology, the type of research conducted, the sample, and methods are discussed. This is followed by section four, the Results, which presents the findings of the analysis. Finally, Section 5 presents the Discussion and Conclusion which addresses the research questions based on the obtained results and provides an overview of the contributions and limitations.

2 Literature Review

2.1 Digital Technologies for Sustainability

The increasing appeal of digital technologies and the growing, if not universal, consensus on the need to build a sustainable future are two leading trends in society (P. Jones & Wynn, 2021). The matter of digital transformation is becoming a constant topic in academic research. Over the past few years, advanced technology was set to offer ground-breaking possibilities to monitor and protect the environment (Coalition For Digital Environmental Sustainability, 2022). Many authors claim the potential for various technologies, especially disruptive technologies, to have enormous potential in future sustainable development and reaching the Sustainable Development Goals (Hellemans et al., 2022; Kasinathan et al., 2022). The World Economic Forum, in collaboration with Accenture, states that digital technologies could reduce emissions by 20% by 2050 to meet the International Energy Agency's net-zero trajectory (World Economic Forum, 2022). Nonetheless, not all digitalization approaches and digital technologies are focused on the creation of sustainable value.

Scholars have addressed the double-edged nature of digitalization and the negative, less predictable social, economic, and environmental impact that arises with digital technologies (Bohnsack et al., 2022; D'Cruz et al., 2022). D'Cruz et al. (2022) focus on the ethical concerns of digital technologies, highlighting accountability as a crucial topic when it comes to the implementation of digital technologies such as AI and automated decision-making in organizations. Digital technologies can lead to various negative influencing factors toward sustainable development. The rise of e-commerce has led to the ease of overconsumption and access to an abundance of products and services (Ah Fook & McNeill, 2020), digitalization of data is causing a range of negative social challenges such as data privacy, cyber security, and digital violence (Bondarenko et al., 2022; Möller, 2020), and digital technologies could cause an increase of unemployment in certain jobs (Satyro et al., 2022).

Therefore, two perspectives are discussed in this research: Tech for Good, technology aiming for increased sustainability, and Good Tech, focusing on the responsible usage of technology.

2.1.1 Tech for Good

The following section discusses the application of digital technologies in promoting sustainable development. This perspective, also referred to as Tech for Good or 'More Sustainable with Digital Technologies', is substantiated by examples of positive environmental, social, and economic effects that arise from the adoption of digital transformation (Bohnsack & Rezazadeh, 2023). The impact is evident in various models, including the three-pillar perspective of sustainability, which covers economic, social, and environmental factors, as well as on a firm, societal, individual, and industry level.

Regarding environmental influences, digital technologies show significant effects (Bohnsack & Rezazadeh, 2023). The adoption of digital technology can drive significant changes in production, services, consumption, and marketing (Bai et al., 2022; Bohnsack & Rezazadeh, 2023). Improvements can be found in long-haul transportation (Haftor & Climent, 2021), manufacturing and circular economy (Di Maria et al., 2022; Yu et al., 2022), fostering the reduction of global emissions and the use of renewable energy (Pinheiro et al., 2022). On an industry level, the implementation of digital technologies enabled the development of smart grids optimizing conventional power grids, resulting in lower energy consumption and, consequently, lower emissions (Narula et al., 2021) and the reduction of energy waste by enabling intelligent energy production and distribution equipment (Ghobakhloo & Fathi, 2021). At the firm level, the implementation of digital technologies has led to the enhancement of business process automation and decision-making (Denicolai et al., 2021), reduction of energy and water consumption, and minimization of waste disposal (Yu et al., 2022). Regarding individual levels, substantial improvements were found in moving towards a paperless society (Balasubramanian et al., 2022), using smart devices for energy efficiency in smart buildings (Metallidou et al., 2020), and traveling using virtual reality technology (Talwar et al., 2023).

Regarding the effects on the social environment, digital technologies have had a positive impact on society regarding healthcare (Hosan et al., 2022), training and education services (Tiwari & Khan, 2020), and access to information and ease of communication (Siltori et al., 2021). At the industry level, new products and services are enabled (Chiarini et al., 2020; Sund et al., 2021), allowing previously inaccessible services and populations to be reached. At the organizational level, the application of digital technologies has facilitated the creation of more streamlined processes, leading to enhanced customer experience and better product design (Kamble & Gunasekaran, 2023) and reduced costs and enhanced quality (Kiel et al., 2017). Further, digital technologies have expanded individual access to information, services, and communication, ultimately enhancing the quality of life of employees (Chen & Chiu, 2018; Felsberger et al., 2022) and fair working conditions (Fatimah et al., 2020).

Finally, considering the economy, digital technologies bring positive effects. At a societal level, these technologies have allowed for improved human impact throughout the supply chain (Kazancoglu et al., 2023; Sharma et al., 2021) and ethical supply chain development (Mahroof et al., 2021). Digital technologies enhanced the industry by enabling new markets and services (Haftor & Climent, 2021) and increased efficiency and cost savings

(Fallahpour et al., 2021; Tseng et al., 2022a). At a firm level, automation of processes by digital technologies increased productivity (Abdul-Hamid et al., 2021). Further, sustainable entrepreneurs incorporate digital technologies into their business models to maximize the creation of social and environmental value (Gregori & Holzmann, 2020), increasing sustainable investing (Dahlman, 2023) as well as cost savings (Balasubramanian et al., 2022). For individuals, access to education (Haleem et al., 2022) and job markets (Dabić et al., 2023) increased through digital technologies, resulting in improved career opportunities (Bohnsack & Rezazadeh, 2023).

However, while the 'Tech for Good' perspective may provide insight into the sustainability outcomes of digital transformation, its underlying assumptions appear to undervalue the potential negative implications of digital technologies (Bohnsack et al., 2022). Therefore, the following chapter focuses on the sustainable implementation of technologies and their responsible usage.

2.1.2 Good Tech

According to Bohnsack & Rezazadeh (2023), responsible digital technologies, also known as 'Good Tech', concentrate on designing and implementing digitally enabled solutions that follow sustainable development principles. While digital transformation has a significant positive impact on the environment, society, and economy, it also uncovers adverse effects resulting from the use of digital technologies, mainly through indirect employment (Bohnsack & Rezazadeh, 2023). Therefore, to ensure objectivity, it must be noted that the impact of digital technologies on sustainability is not always positive. It is estimated that digital pollution accounts for 4% of global greenhouse gas emissions, which is greater than the aviation industry's share (Binder & Wade, 2023). Therefore, digital technologies must be implemented more responsibly and sustainably.

From an environmental perspective, an increase in e-commerce results in overconsumption (Fook & McNeill, 2020), leading to increased production and pollution through inadequate waste management (Akram et al., 2019; Tseng et al., 2022). Another negative impact is the huge server farms needed for digital platforms, which are powered by electricity and cooled by large amounts of water, creating a large carbon footprint (Al Kez et al., 2022; Bohnsack & Rezazadeh, 2023).

From a societal viewpoint, digital technologies have caused a rise in overuse and addiction to digital platforms (Şirin & Ketrez, 2023). Consequently, there has been a decline in physical social interactions, adversely affecting both mental and physical well-being (Bohnsack & Rezazadeh, 2023). Further, the substitution of human labor with digital technologies increases unemployment (Satyro et al., 2022), which has significant consequences for society and well-being. Lastly, cyber security and privacy breaches are concerns for society when considering the usage of digital technologies (Fink et al., 2017; Garcia-Perez et al., 2023).

From an economic perspective, several beneficial results can be observed as mentioned in Chapter 2.1.1. Nevertheless, negative impacts still occur for the economy due to decreased demand for workers leading to a decline in wages (Satyro et al., 2022).

Overall, digital technologies have both positive and negative effects. Yet, it is crucial to acknowledge the potential negative outcomes and take measures to minimize the unwanted effects mentioned. Therefore, a combination of the two guiding perspectives, 'Tech for Good' and 'Good Tech', is necessary for a thorough contextual comprehension of sustainability in the digital era (Bohnsack & Rezazadeh, 2023).

2.2 Sustainable Development

Defining sustainability is challenging due to the absence of a consistent definition, varied synonyms or interpretations, and different approaches to understanding the term, depending on the given context (Moore et al., 2017). Nevertheless, the Brundtland Report (Brundtland, 1987) provides the most widely accepted definition of sustainability. In the report, Gro Harlem Brundtland, former Prime Minister of Norway, defined sustainable development as meeting current needs without endangering the capacity to meet future generations' needs. Another common descriptor of sustainable development are the three pillars; namely, economic, social, and environmental, as seen in Figure 1 below (Purvis et al., 2019). The three pillars are interconnected rings, creating a simple concept and thus facilitating analysis and making it more straightforward (Giddings et al., 2002) Purvis et al. (2019) referred to the guide established during the United Nations Summit in 1992, which outlines the goal of the three pillars of sustainable development. These pillars aim to achieve balanced economic growth, enhanced social equity, and environmental protection. However, it is not always possible to pursue the goals of all pillars simultaneously. The three dimensions of sustainability must be comprehended as a holistic system, in which interdependencies are taken into account to facilitate effective decision-making, as they are all closely linked and changes in one might affect other pillars (Fischer et al., 2023).

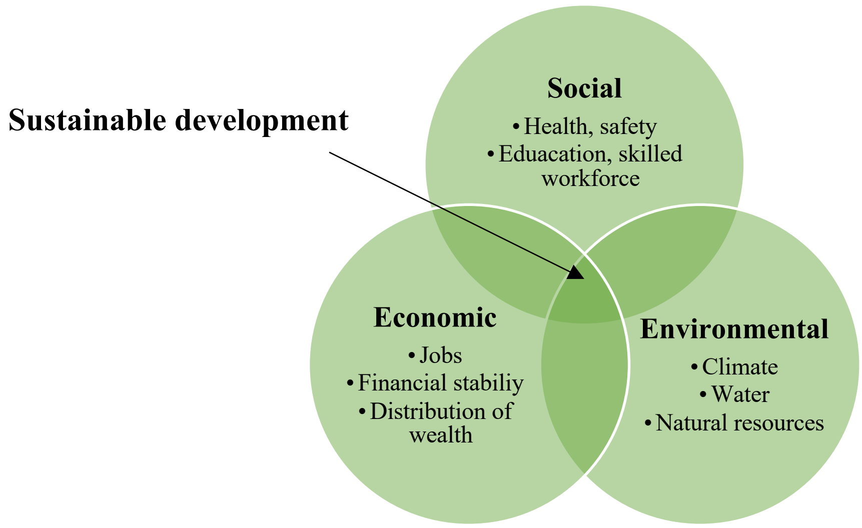

Figure 1: Three pillars of sustainable development (Purvis et al., 2019, Barbier & Burgess, 2017)

Even though the pillars are illustrated in a balanced manner, highlighting a symmetrical interconnection, varying perspectives may assign greater importance to one pillar over another (Giddings et al., 2002). When pursuing economic objectives such as improved efficiency, fairness and decreased poverty, unintended environmental and social impacts can still occur. However, attaining sustainable development requires balancing the trade-offs between the different objectives of all three pillars (Barbier & Burgess, 2017).

Sustainable development requires the inclusion of the Sustainable Development Goals (SDGs). The 2030 Agenda for Sustainable Development, agreed by all United Nations Member States in 2015, offers a communal strategy for peace and well-being for people and the planet, now and in the future. It comprises the seventeen SDGs which urgently demand action from all countries - developed and developing - in a global partnership (United Nations, n.d.). Further, the goals can be put into perspective of the three pillars as the following. Sixteen of the seventeen SDGs can be classified into three dimensions: economic, social, and environmental, as presented in Figure 2. The 17th goal, which is partnerships to achieve the goals, entails all of these dimensions as its objective is to foster cooperation between them (Stockholm Resilience Centre, 2017).

Figure 2:17 SDGs in connection with the three pillars of sustainability (Stockholm Resilience Centre, 2017)

2.2.1 Environmental

One pivotal step towards environmental problems was the UN Conference on Human Environment held in Stockholm in 1972. Twenty-six principles were formulated as a result of the conference, with the majority addressing environmental issues (United Nations, 1972). The Stockholm conference was instrumental in driving the creation of various environmental protection topics, such as maintaining the earth's ability to produce vital renewable resources. The idea of environmental sustainability concerns the natural surroundings and its ability to maintain productivity and resilience for the support of human life. Concerning the integrity of ecosystems and the carrying capacity of the environment, environmental sustainability requires the sustainable utilization of natural capital as a source of economic inputs (Brodhag & Taliere, 2006; Goodland & Daly, 1996). Initially, sustainability was not a priority for corporations, and they mainly addressed environmental issues and crises reactively to minimize their effects (Berry & Rondinelli, 1998). Only in the 1990s did corporations start integrating sustainability strategies into their management processes, introducing Environmental Management Systems (EMS). These systems strive to integrate procedures and practices for training staff and reporting environmental performance information to internal and external stakeholders (Melnyk et al., 2003).

2.2.2 Social

Social sustainability includes principles of fairness, empowerment, accessibility, participation, cultural identity, and institutional stability (Daly, 1992). This idea suggests that people are crucial to the development (Benaim et al., 2008). Essentially, social sustainability involves a social system that addresses poverty (Littig & Griessler, 2005). However, in a broader sense, social sustainability is concerned with the intersection of social issues such as poverty and environmental degradation (James & Magee, 2016). In this context, the concept of social sustainability asserts that the mitigation of poverty must not result in excessive environmental harm or economic instability. It must aim to improve poverty within the existing environmental and economic resource base of society (Scopelliti et al., 2018). According to Saith (2006), social sustainability involves promoting the growth of individuals, communities, and cultures to enable a purposeful life via adequate healthcare, education, gender equality, global peace, and stability. Realizing social sustainability is difficult due to the complex and daunting nature of the social dimension as, unlike the environmental and economic systems, where flows and cycles are readily observable, the dynamics within the social system are highly intangible and challenging to model (Benaim et al., 2008; Saner et al., 2020). Social sustainability is not aimed at guaranteeing the satisfaction of everyone's needs. Instead, it is about creating empowering circumstances that enable individuals to fulfill their needs at their discretion (Kolk, 2016). Social responsibility covers a wide range of the Sustainable Development Goals, with poverty, employment, family, and social inclusion being some examples (United Nations, n.d.). Understanding the nature of social dynamics and how these structures arise from a systems perspective is crucial for achieving sustainable development.

2.2.3 Economic

Economic sustainability entails a production system that meets current consumption levels while safeguarding future needs (Lobo et al., 2015). Historically, economists placed excessive emphasis on the market's ability to efficiently allocate resources to the assumption that natural resources were endless (Mensah, 2019). However, it has since become clear that natural resources are not infinite and not all of them can be replenished or renewed. The expansion of the economic system has surpassed the available natural resources, leading to a re-evaluation of the traditional economic ideologies (Basiago, 1998). This has resulted in numerous scholars questioning the viability of unhindered growth and consumption (Boström & Klintman, 2019; Gumbert et al., 2022; Paech, 2013). The UN Division for Sustainable Development Report highlights that human life on Earth is dependent on the use of the planet's limited natural resources (Allen & Clouth, 2012). Dernbach (2003) argued that population growth results in an increased demand for essential human needs, such as food, clothing, and housing. However, the resources available in the world cannot be expanded indefinitely to satisfy these needs forever. Moreover, Retchless and Brewer (2016) state that because the main concern seems to be economic growth, important cost components, such as the impact of exhaustion and pollution, are ignored, while increasing demand for goods and services continues to drive markets and violate destructive environmental impacts (Mensah, 2019). Therefore, to achieve economic sustainability, decisions must be made in a fair and fiscally responsible manner, while considering other perspectives and their impact on sustainability (Zhai & Chang, 2018).

2.3 Artificial Intelligence

2.3.1 Definition

For more than half a century, AI remained an area of relative scientific obscurity and limited practical interest. Today, with the rise of big data and improvements in computing power, it has entered the business environment and public conversation. AI is commonly defined as a system's ability to interpret external data correctly, to learn from such data, and to use those learnings to achieve specific goals and tasks through flexible adaptation (Haenlein & Kaplan, 2019). Generative artificial intelligence (Gen AI) based on transformer machine learning models, including Generative Pretrained Transformer (GPT) and its chatbot application ChatGPT, has become user-friendly and more accessible to end-users. This has made AI more approachable and less restricted to specific groups like software engineers, for example.

Generative AI is an umbrella term used to describe machine learning solutions that are trained on large amounts of data to generate output based on input from user commands (Sætra, 2023) and sophisticated text indistinguishable from that produced by a human (Dwivedi et al., 2023). The versatility of Large Language Models (LLMs) has made them general-purpose technologies. This has led to a global phenomenon where end-users and employees are experimenting with AI to enhance productivity (Bilgram & Laarmann, 2023). The impact of AI is anticipated to affect global productivity, equality, inclusion, and environmental outcomes in the short and long term. These impacts reveal both positive and negative consequences for sustainable development and organizations, society, and individuals (Dwivedi et al., 2023; Vinuesa et al., 2020). Vinuesa et al. (2020) found that AI has a positive effect on 79% of the SDGs by leveraging technological advancements to overcome current constraints. However, the advance of AI also may hinder 35% of the SDGs.

2.3.2 Two dimensions of AI

Although negative impacts are relatively smaller, their consideration is crucial. In general, the dynamics of AI on sustainability can be separated into predictable, or intended first-order outcomes and unintended, second-order consequences, fostering the responsibility of firms and individuals to mitigate the risks and potential negative outcomes (Bohnsack & Rezazadeh, 2023). Here, first-order consequences indicate the primary goal of the use of AI, focused on the intended and expected results towards sustainable development, while second-order consequences relate to unexpected, indirect, and cumulative effects that were not planned when using AI for sustainability (Bohnsack & Rezazadeh, 2023).

Therefore, two perspectives can be identified: AI for sustainability and AI done responsibly. The Louts Framework[1] shown in Figure 3 enables the analysis of the perspectives mentioned, the left side shows the three types of impacts expected on sustainable development, looking at each pillar of sustainability, environmental, social, and economic, while the right side of the framework covers the three expected outcomes of responsible use of AI. In the following, both intended and unintended outcomes of digital technologies, especially AI will be discussed more detailed.

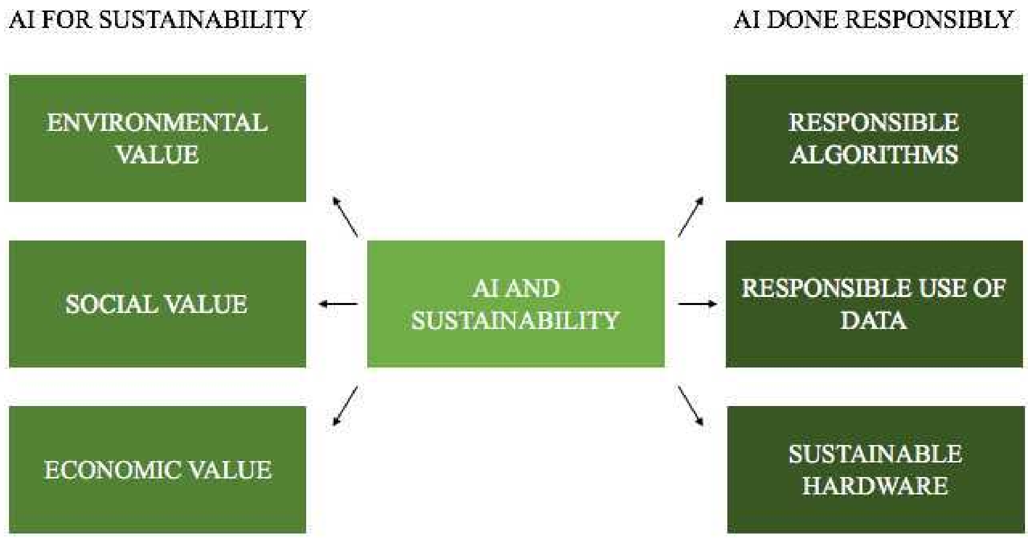

Figure 3: Lotus Diagram AI and Sustainability (adapted from Bohnsack & Rezazadeh, 2023)

AI for Sustainability encompasses the three dimensions in which AI aims to enhance sustainability by creating economic, social, and environmental value. Therefore, the left side of

[1] The Lotus Diagram is a 3×3 grid brainstorming and conceptualization tool for visualizing different components and dimensions around a core concept, by Michael Michalko, a creativity expert and author of the influential Mindset books.

the framework refers to the Tech for Good part described in Chapter 2.1.1., where technology is focused on improving sustainable development. On the other hand, the right side of the framework refers to responsible technology, where the focus lies on using AI tools in a sustainable and environmentally friendly way. This side is related to the Good Tech perspective with a focus on designing and implementing digitally-enabled solutions in line with sustainable development criteria and mitigating the risks described in Chapter 2.1.2. (Bohnsack & Rezazadeh, 2023).

While the social, environmental, and economic perspectives on the left-hand side have already been addressed in Chapter 2.2. on Sustainability, further clarification is still required for the right-side dimensions.

An algorithm is a sequence of instructions in the form of computer codes designed to achieve a result. Digital platforms use algorithms to analyze user data and improve the user experience by personalizing offers and communications offers and communications (Eg et al., 2023). Although Machine Learning algorithms embedded within AI represent some of the most promising tools for various industries (marketing, medicine, and healthcare, etc.) in terms of their first-order effects, there are also second-order effects that need to be considered (Bohnsack & Rezazadeh, 2023). Despite these advantages, it is important to recognize that algorithmic solutions may be prone to both statistical bias (Sinha et al., 2023), as referred to as the possibility of producing an output deviating from the true estimate - and social bias (Aquino, 2023), meaning disparities that may lead to suboptimal outcomes for certain groups of the population. Therefore, responsible use of algorithmic learning and decision-making is crucial to prevent and address such biases. To reduce the unintended impact of algorithms, companies can enhance algorithm transparency by disclosing how data is collected and utilized. Additionally, ethical, and fair implementation of AI algorithms can be strengthened through approaches such as privacy by design (Bohnsack & Rezazadeh, 2023).

Responsible use of data is the second aspect of how gen AI can be used more responsibly. IoT-based cloud computing enables businesses to collect real-time data from connected devices and further train AI models with input data and monetize user interaction data (Akpan et al., 2022; Dehghani-Dehcheshmeh et al., 2023). Therefore, data security needs to be focused on in terms of social sustainability. While AI-enabled endpoint protection exists, it comes with trust and privacy concerns, as the AI model needs direct access to local data for endpoint protection systems to work. In addition, users tend to over-rely on these systems and mistakenly believe that these systems offer absolute protection (Butavicius et al., 2020).

The third aspect of AI done responsibly is sustainable hardware. Hardware comprises machines, equipment, chips, sensors, and other physical components that are employed in computer systems or electronic devices (Chiarini et al., 2020). Advanced hardware is needed for gen AI training, utilizing massive amounts of data and performing complex tasks with maximum speed and efficiency (Bohnsack & Rezazadeh, 2023). While hardware advancements are enhancing the efficiency and dependability of AI tools, there have been concerns raised about potential unintended environmental and social effects. Despite their intended effects, such as reducing paper waste and eliminating physical documentation, there is evidence to suggest that memory offloading could negatively impact employees' ability to recall and manage data-related tasks from their memory, potentially leading to unwise and ill-considered decision-making (Mastrogiorgio et al., 2021; Tlili et al., 2023). Additionally, the high energy requirement and cooling systems for data centers and hardware are critical aspects regarding sustainability (Vinuesa et al., 2020).

2.3.3 Consequences of AI

2.3.3.1 Anticipated consequences

Anticipated consequences highlight the planned positive effect of AI on sustainable development. The expected outcome is the value creation for social, environmental, and economic sustainability (Bohnsack & Rezazadeh, 2023). According to Vinuesa and colleagues (2020), AI can act as an enabler towards no poverty, quality education, cleaner water and sanitation, affordable and clean energy as well as sustainable cities, when focusing on social outcomes. Technology can act as an enabler by supporting the provision of food, health, water, and energy. Smart water management systems powered by AI replicate human learning in a dynamic environment that optimizes decision-making and investments in water management infrastructure (Goralski & Tan, 2020). Regarding the economy, the most stated positive effect of AI is increased productivity (Acemoglu & Restrepo, 2018). For environmental impact, AI can be leveraged for analytical usage. Analyzing a large number of databases to derive joint actions to preserve our environment, for fast indications from satellite images regarding vegetation (Jean et al., 2016), and automatic identification of oil spills, decreasing marine pollution (Keramitsoglou et al., 2006).

2.3.3.2 Unanticipated consequences

Unanticipated consequences and second-order effects of AI for sustainable development can be both positive and negative. Nevertheless, it is crucial to mitigate the negative impact by ensuring the responsible use of AI by firms and individuals (Bohnsack & Rezazadeh, 2023). This perspective highlights the need for responsible use of algorithms, data, and hardware.

As the implementation of AI might differ from country to country, influenced by culture and wealth, this might foster inequality. AI needs high energy requirements, cooling systems for data centers, and the technology's carbon footprint is critical (Vinuesa et al., 2020). Another significant limitation of AI-based advancements is that they are typically grounded in the requirements and principles of the countries in which AI is being developed and if big data are implemented in regions where there is no ethical inspection, openness, and democratic governance, there is a risk that AI could promote nationalism, discrimination against minorities, and sway election results (Helbing & Pournaras, 2015). The absence of variety among datasets is a cause for concern overall. This is affecting stereotypical thinking and discrimination among minorities (Bolukbasi et al., 2016). The inequalities of distribution of AI also adapt to economic sustainable development and thus negatively affect SDGs regarding economic growth, decent work, and innovation. The heavy energy consumption associated with AI is an important consideration when evaluating its environmental footprint (Jones, 2018).

Below the first- and second-order effects of AI are summarized. The first-order effects are the intended and deliberately planned results that the creators and users of generative AI solutions expect. Second-order effects refer to the mentioned unintended consequences of AI. The diagram covers all effects mentioned in the previous chapters, from the Good Tech and Tech for Good perspectives, as well as the just mentioned intended or unintended consequences of AI.

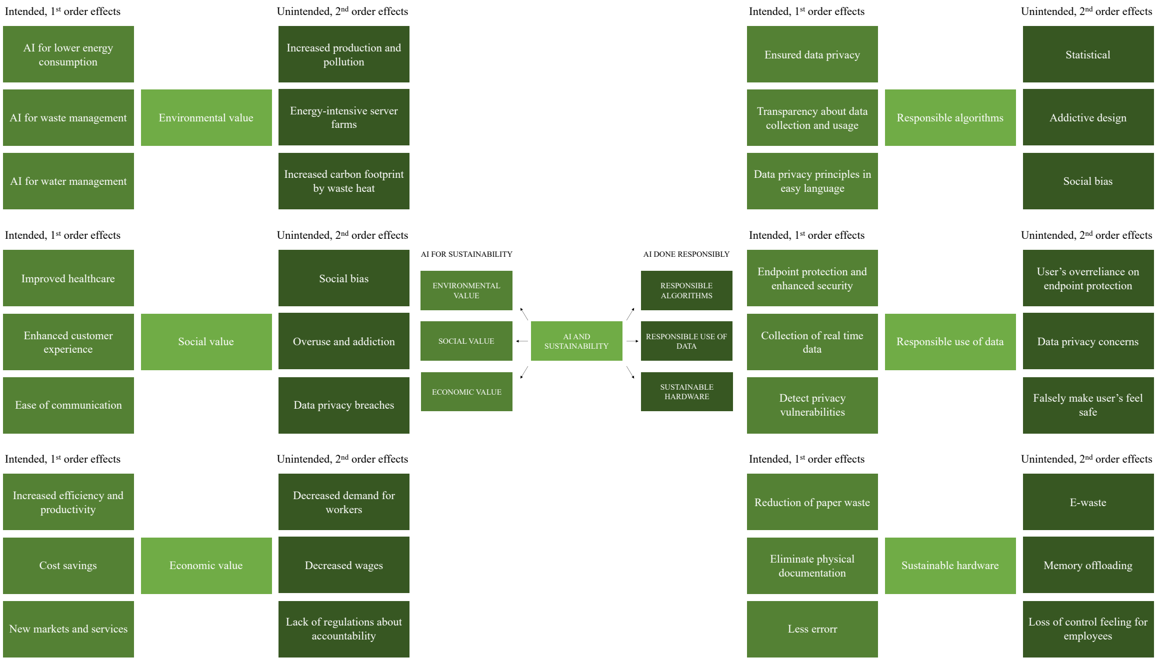

Figure 4: Gen AI's first and second-order effects

2.4 Sustainable Fashion

2.4.1 Definition

Muthu (2019) defines sustainable clothing as garments that are designed for extended use, produced in ethical manufacturing systems without causing harm to the environment and workers, and adhere to fair-trade principles with sweatshop-free labor conditions. Roozen et al. (2021) also notes that sustainable apparel is sometimes used interchangeably with the term 'slow fashion'. Slow fashion is the opposite of fast fashion, which is characterized by rapidly shifting consumer preferences and fast production processes (Roozen et al., 2021; Christopher et al., 2004). Sustainability in the fashion industry has gained the utmost attention due to increased consumer concern for the environment. Accordingly, firms should shift their focus toward sustainable product strategies that cater to the changing preferences of consumers (Yang & Dong, 2017). According to McKinsey & Company (2020), the fashion industry was responsible for approximately 2.1 billion tons of GHG (Greenhouse Gas) emissions in 2018 alone. Most of these emissions originated from material production, preparation, and processing. The apparel and textile industry supply chain entails laborious manufacturing processes, lengthy value chains, and a marked propensity towards environmental pollution (Cai & Choi, 2020).

2.4.2 Opportunities for AI in Sustainable Fashion

This chapter provides an objective analysis of how AI can enhance sustainability in the fashion industry. The industry is infamous for its adverse effects on sustainable development; thus, this chapter aims to identify areas in which AI can mitigate or improve such effects.

One of the major problems in achieving sustainable fashion is the effective management of overproduction (Payne & Mellick, 2022). Stockpiling in the fashion sector produces huge amounts of waste, as trends change rapidly. To tackle this issue, implementing predictive analytics with the aid of AI could potentially serve as a viable solution (Rever, 2023; Sanvt Journal, 2023). Companies often invest significant resources in forecasting and designing for trends, which frequently results in the manufacturing of clothing that remains unsold. However, AI is emerging as a solution, leveraging advanced data analytics and machine learning to forecast sales and thus reducing overproduction (Rever, 2023). This reduces significant uncertainties and human errors, enabling investments in garments that are likely to be sold. Through the analysis of this data, brands may effectively streamline production processes, mitigating the possibility of overstocking and minimizing waste (Sanvt Journal, 2023). For example, the French conglomerate LVMH has joined forces with Google Cloud to utilize AI and cloud-based solutions for improved stock management, and forecasting (LVMH, 2021).

Additionally, digital technology can help minimize overproduction by eliminating the need for physical resources, as many negative social and environmental impacts come from the production itself and physical prototyping (Binder & Wade, 2023). Binder and Wade (2023) suggest that digital tools such as digital twins or 3-D printing can help to dematerialize the production process.

Another opportunity for AI to improve the fashion industry in terms of sustainability is to ensure sustainable supply chains and sustainable material sourcing (Milton, 2023; Sanvt Journal, 2023). Many clothing brands undergo third-party environmental compliance audits to ensure compliance with environmental regulations for themselves and their suppliers (Wren, 2022). However, these audits only serve as a partial step towards more sustainable clothing production, neglecting several aspects of sustainability. Moreover, monitoring the sustainability practices of every supplier and the quality of their products may pose a challenge for larger corporations (Milton, 2023). According to Milton (2023), AI can assist fashion brands in assessing the sustainability of their supply chain. AI tools can analyze supplier information to examine their sustainability practices. Prewave, an AI company already working with Audi, KTM, and other big brands, has developed a tool that utilizes AI and machine learning to scour the Internet for any reference to a company's suppliers and alert the company to possible sustainability breaches (Prewave, 2023). This AI tool shows potential in assessing a supplier's compliance with ethical labor practices and anti-corruption measures which, implemented in the fashion industry, can help with supplier selection and monitoring process, ensuring sustainable practices and materials.

AI facilitates sustainable shopping practices by making thrifting more accessible. Thrifting, or buying pre-owned clothing, is an excellent environmentally friendly option since it lowers the demand for new garments, ultimately contributing to reduced carbon emissions and a decrease in waste and pollution from the production process (Charnley et al., 2022; Farrant et al., 2010). Companies like Faircado are using AI to provide second-hand recommendations to their customers while shopping online (Raidl, 2022). The software suggests various second-hand goods, from fashion to books, to reduce overconsumption and save natural resources.

Finally, AI's ability to process large amounts of data not only optimizes operational efficiency but also empowers companies to make well-informed decisions that contribute directly to a more sustainable and ecologically conscious approach (Binder & Wade, 2023).

2.4.3 Challenges of AI in fashion

This chapter provides an objective analysis of how AI is facing particular challenges in the fashion industry Those challenges arise mainly because AI is still advancing in this industry, and there are not yet enough regulations in place.

One issue is that the legal boundaries surrounding the use of generative AI are still being clarified (Walsh, 2023). The interface between AI and copyright law presents complex challenges, particularly in the context of fashion design (Haug Partners, n.d). The utilization of AI to create fabric patterns, colors, and silhouettes leads to concerns regarding ownership, particularly when these designs include contributions from both machines and humans (Haug Partners, n.d). Designers can receive critiques for producing derivative or imitative designs. The ownership of intellectual property and creative rights to AI-generated works, which may draw on a range of multimodal data sources, including past collections of other designers, will be determined on a case-by-case basis until a lasting legal precedent is established (McKinsey & Company, 2023). The dispute between Hermès and artist Mason Rothschild over MetaBirkin NFTs, which resulted in a judge ruling that the NFTs violated Hermès's trademark, serves as a prime example of how fashion brands can encounter legal dilemmas when confronted with novel technologies (Small, 2023). Another issue of great concern regarding the implementation of AI in the fashion industry, as well as in other businesses using AI in general, pertains to potential privacy implications. Responsible use of data should be addressed when implementing AI tools into business. Numerous AI technologies acquire vast amounts of consumer data which companies utilize for market adaptation, trend identification, and tracking competitor activities via the internet and social media (Haug Partners, n.d). Further, many organizations seem to tackle sustainability and digital technology advancement separately, daunting the possible combined value (Binder & Wade, 2023).

Given the rapid development of AI and the use of big data, novel applications of AI will be identified by the fashion industry. However, the implications and challenges of AI, which remains largely unregulated may contribute to new legal issues. Therefore, the law must focus on addressing the intersection of AI with intellectual property and privacy concerns to prevent potential threats to innovation. Additionally, the parameters of ownership and protection of intellectual property and data need to be better defined.

2.5 Potential Gaps of the Literature Review

The literature review offered a comprehensive introduction to the use of AI for promoting sustainability. It emphasizes that comprehending sustainability in the digital era requires an all-encompassing evaluation of the 'Tech for Good' and 'Good Tech' perspectives.

Recognizing potential negative consequences objectively is crucial. Therefore, responsible and sustainable implementation of digital technologies is imperative, alongside responsible employment of AI tools such as algorithms, data, and hardware to advance sustainable development objectives. Sustainable fashion faces challenges related to supply chain sustainability and overproduction. AI offers significant opportunities to address these concerns, including waste reduction and promoting thrifting. Legal and privacy considerations necessitate careful deliberation and regulation for the responsible adoption of AI in the fashion industry.

When identifying gaps in the field of sustainable digitalization, it is evident that the existing literature primarily concentrates on the ecological effects of technology. However, there is limited understanding of the economic and social consequences. Overall, there is a gap in research on AI and its challenges, particularly in the fashion industry, both in high-end journal articles and grey literature. Articles usually concentrate on how AI can boost business performance across a variety of use cases. This review has established that, so far, there has been more concentration on Tech for Good perspectives, which assess the environmental, social, and economic consequences of digital technologies. However, there appears to be a scarcity of responsibly conducted research in the field of AI in comparison to the former viewpoint. This deficiency may stem from AI's recent growth in various industries without sufficient prior research.

3 Methodology

This paper aims to investigate the potential uses of AI for sustainable practices in the fashion industry, with a specific focus on the predicted and unpredicted outcomes of such technology. Following a well-structured methodology enhances the reliability and validity of the results obtained through systematic research.

3.1 Research approach

To accomplish the objective just stated, a qualitative research method involving semi-structured interviews with industry experts was employed. The primary challenge of qualitative research is to expand the theoretical viewpoint beyond the existing literature by employing an inductive methodology (Saunders et al., 2009). The chosen methodology followed an inductive approach as it is suitable for researching an emerging topic that is the subject of considerable debate but for which there is still little existing literature (Saunders et al., 2019). The research objective will be examined through analysis of primary data, which will then be compared to the literature review findings. The aim is to develop new theories based on the results of both, primary and secondary data. This research methodology is appropriate for the subject under analysis as it is an emerging area of research.

3.2 Sample

Data was collected from individuals to identify topics that further allow for the development of theories. Therefore, an exploratory qualitative design, with industry experts selected as the sample, was conducted. The interviewees were selected through purposive sampling, a non-probability method based on the researcher's judgment. If the target population for the study is scarce or very difficult to find and recruit, purposive sampling may be the only option (Swanson & Holton, 2005). The selection criteria were based on the interviewee’s experience in the sustainable fashion and tech industry as well as the ability to contribute insightful answers to the research questions and provide relevant knowledge. The description of the sample used in this research for primary data is presented in the table below (Table 1). Moreover, ease of contact and potential willingness to take part were further criteria for being selected.

Interview Partner	Position	Background	Experience in years
1	COO	Technology	3
2	Co-Founder and CEO	Business	4
3	Co-Founder	Business	4
4	Operations Manager	Business	1

Table 1: Interviewee profile

Given the limitation in conducting additional interviews, reports of projects funded by the EU Research & Development projects as well as reports of renowned management consultancies were used as secondary data. The summary of all reports included in this research is presented in the table below.

Type of source	Source	Title	Pages
Consultancy report	McKinsey & Company & Business of Fashion, 2023	The State of Fashion 2024	128
Consultancy report	Boston Consulting Group, 2023	How AI Can Speed Climate Action	37
Consultancy report	McKinsey & Company, 2023	Generative AI: Unlocking the future of fashion	7
EU funded project	European Commission, 2019	FashionBrain	4
EU funded project	European Commission, 2020	New tools to digitalize wasteful fashion industry.	4
European Council	European Council, 2023	Artificial intelligence act	3

Table 2: Secondary data reports

3.3 Data collection and methods

Semi-structured interviews will be prepared in advance, with certain questions or topics identified, but lines of inquiry will be pursued during the interview to investigate noteworthy and unanticipated topics as they arise. (Blandford, 2013). Semi-structured guidance enables a dynamic and fluid investigation, leading to more valuable findings (Rubin & Rubin, 2011).

The data collection process can be split up into six steps: (i) determine what information needs to be collected; (ii) research and contact potential industry experts; (iii) conducting the interviews; (iv) collecting and summarizing the data; (v) analyzing the data and (vi) comparing the findings with the secondary data reports.

Figure 5: Data collection process

The selection process of information to be collected was based on the findings of the literature review. As semi-structured interviews require some topics to be prepared as a guideline through the process, the topics were focused on the sustainable fashion industry, AI implementation, its possibilities and challenges, responsible algorithms, and future directions for AI in sustainable fashion. To avoid losing data, the interviews were tape-recorded, while ensuring the confidentiality of the interview itself. On average, the interviews lasted 30 to 50 minutes. Industry experts, preferably entrepreneurs in the fashion and tech field were mainly found on and contacted through LinkedIn. Due to the emerging and specific topic of AI and sustainable fashion, only four semi-structured interviews were conducted in the end.

3.4 Data analysis

The Gioia Method (GM) is a qualitative approach to developing data analysis that adheres to the rigorous standards of trustworthy research (D. Gioia, 2021; D. A. Gioia et al., 2013). According to Gioia (2021) and Gioia et al. (2013), this is a holistic method for concept development that balances the often conflicting need to develop new concepts inductively while meeting the high standards of rigor required by leading journals. The GM follows the following procedure: the data is organized according to categories. The first step in the analysis includes a comprehensive examination of the raw data, both from interviews and secondary data, the 'concepts'. Similar quotes were systematically aggregated into distinct, non-redundant concepts. Categories of primary codes are established by identifying and categorizing the most commonly used words, phrases, and terms from both participant input and secondary data. The analysis is conducted with consideration for objectivity. These categories accurately depict the viewpoints of the interviewees and reports concerning the research questions. The second level, 'topics', possesses a theoretical nature. This process is iterative, where second-order themes are recognized, forming conceptual frameworks arising from the combination of the first-order categories. These themes embody distinct theoretical concepts that further enhance our understanding of the data. Before the onset of the 'aggregate dimension', which forms the basis of the data structure, the first and second-order themes must first be practically and theoretically categorized to achieve a high level of abstraction in the coding. The Gioia method was employed due to its robust approach to qualitative data analysis, which provides a systematic framework for transforming raw data into rich insights (Gioia et al., 2013) and additionally allows for emergent themes to be derived directly from the data, ensuring that the analysis remains grounded in the actual evidence collected.

4 Results

The findings are categorized in this section based on the research areas explored in existing literature as well as the primary and secondary data collected. These results stem from a qualitative analysis of the data, during which responses were sorted and classified, offering helpful and relevant information regarding the research questions. Using the Gioia method of analyzing qualitative data, the results of interviews are combined with secondary data and categorized into the mentioned categories in Chapter 3.4. To ensure a better overview, the findings were summarized in three different dimensions: *applications, benefits,* and *challenges* of AI.

4.1 Applications

The experts interviewed in combination with secondary data uncovered the main actions and frequently utilized fields for AI application in the fashion industry, based on their experience as entrepreneurs and industry knowledge.

When combining the first-order concepts we can come up with three different themes regarding AI applications currently focused on most. The input provided by interviews and secondary data showed that personalization, second-hand purchasing, and sustainable supply chains are three themes that are already implementing AI for a more sustainable fashion industry. As stated by one COO, Interviewee 1, machine learning combined with browser plug-ins are used for personalized recommendations based on consumers' previous interests, which helps to mitigate overconsumption of goods by users when purchasing textile products that end up being thrown away. '*This further reduces textile waste, as users focus on buying products that fit their lifestyle'* (Interviewee 1). Additionally, personalizing online consumer journeys and offers (for example, web pages, and product descriptions) based on individual consumer profiles is seen as a value-creating use case for AI in fashion (McKinsey & Company & Business of Fashion, 2023). The EU-funded project 'FashionBrain' benefits the fashion industry by using AI to understand customer preferences and predict trends. This innovation streamlines data handling, improves trend forecasting, and enhances the online shopping experience. Personalization is becoming easier with AI due to its ability to process a huge amount of data (European Commission, 2019). Another EU-funded project, also focused on personalization, is using 3D digital avatars of customers to personalize fitting and customize fashion choices, aiming for a future in which garments will only be produced when everything is confirmed by the client (European Commission, 2020). Additionally, Interviewee 3 stated that with personal avatars, using data on body shape, height, usual sizes worn by the customer, etc., help decrease returns, as many returns happen due to sizing issues. '*Many customers tend* *to order more than one size as they are not sure about the fit of the product. This leads to a huge number of returns for companies, which are not always able to be resold and end up being thrown away*' (Interviewee 3). The second theme discovered by the primary and secondary data collection was the improved experience of second-hand shopping. '*Second-hand shopping comes with a lot of pain points; with our machine learning AI technique this becomes easier.*' (Interviewee 1). '*This machine-learning process aims to use browser plug-ins to indicate the same or similar second-hand options while shopping online'* (Interviewee 1). Regarding supply chain improvement, Interviewee 4 revealed the implementation of AI towards a sustainable supply chain. '*Our AI-powered platform analyses millions of online sources in more than fifty languages and identifies risks for certain supply chains. We cover a large range of supplier risks, including human rights issues, sustainability risks, and supply chain compliance*' (Interviewee 4).

In addition to these representative quotations, the corresponding data and coding structure are shown in Figure 6 below.

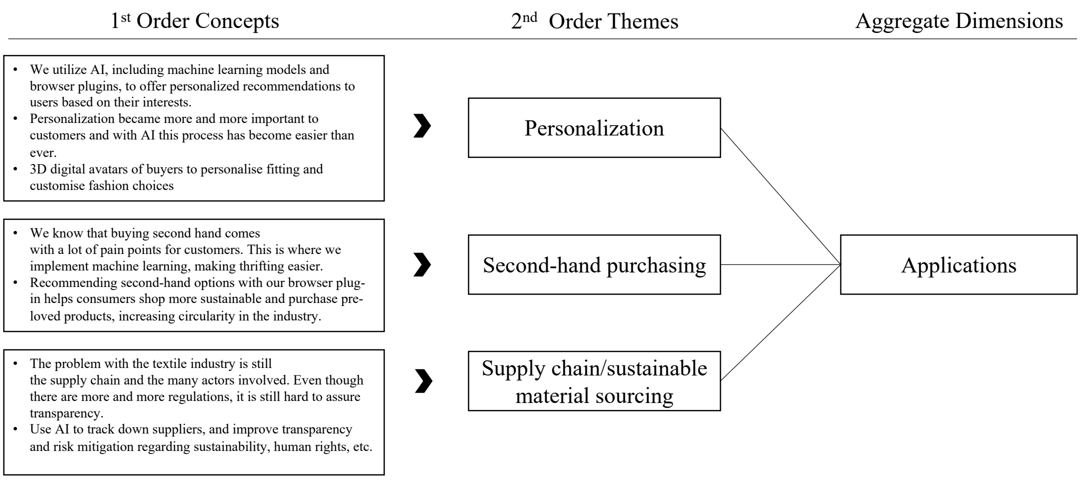

Figure 6:Applications for AI

4.2 Benefits

Regarding the benefits and potential of AI for a more sustainable fashion industry, the following themes were identified: Design and product development, digitalization of upcycling and recycling centers, emission reduction, and supply chain and logistics.

Regarding design and product development, AI can benefit human creatives as it can take over repeating tasks and let the employees focus on the creative work itself (McKinsey & Company & Business of Fashion, 2023). According to McKinsey analysis (2023), as much as one-fourth of generative AI's potential value in the fashion industry may be in design and product development. The second theme developed by analyzing data is the digitalization of upcycling and recycling centers. '*The whole recycling and upcycling industry needs a digitalization booster'* (Interviewee 2). According to the primary data analyzed, textile sorting processes can be improved with AI by enhancing the sorting and quality scanning process of recycled textiles. For emission reduction, AI was especially seen as a benefit due to its ability to analyze large amounts of data (Boston Consulting Group, 2023). The report further highlights that AI can deliver insights, revealing patterns in emissions and suggesting the best ways to prioritize abatement efforts. AI plays a crucial role in both gathering emissions data and matching it to activities and products along the value chain of businesses (Boston Consulting Group, 2023). This is especially helpful for the textile industry due to its extensive value chain. When being able to match emissions to specific activities throughout the supply chain process, businesses can leverage those insights to drive climate action (Boston Consulting Group, 2023). Another benefit appears for supply chain and logistics in terms that insights from multiple data sets can enhance analytics for demand forecasting (McKinsey & Company & Business of Fashion, 2023). Consequently, manufacturers can avoid both over-production and the emissions those unsold goods would produce (Boston Consulting Group, 2023). The final benefit identified from the analysis is the improved sampling and development process, where AI can help reduce textile waste during the production stages by processing image and text data, sketches, and data on customer behavior using AI software, thus reducing the number of prototypes developed during the process. *'The technology reduces the need for extensive testing and prototyping, which usually ends in a lot of textile waste or unfinished products'* (Interviewee 3).

In addition to these representative quotations, the corresponding data and coding structure are shown in Figure 7.

4.3 Challenges

Regarding the challenges and risks that might occur with the usage of AI, especially in the fashion industry the following topics were mentioned. The challenges were categorized into two aggregated dimensions, ethical and technological challenges.

'Companies operating at the convergence of technology and fashion face a daunting task - complying with strict data privacy laws. The complexity arising from these regulations impacts the implementation of innovative technologies, especially here in Germany' (Interviewee 1). The European Council finalized a first draft of rules for AI, focusing on a 'risk-based' approach: the higher the risk for harming society, the stricter the rules. Those regulations might make it difficult for AI implementation for personalization tools. '*Despite the simple demand for email addresses, a proportion of users hesitate to register, probably by a*

predominant worry for the security of their private information' (Interviewee 1). The data showcases that consumers are still not yet fully aligned with exposing their data. '*Explaining to customers how the AI is implemented into the process and how data is used should be focused on. Due to the emerging topic of AI, many customers do not understand what is happening with their data and how the process works. Explaining it [the process] to them in an understandable language would probably bring more customers and increase their trust in the service'* (Interviewee 3). However, data privacy is not only focused on the fear of people giving their information. Intellectual property rights emerge as a complex facet of AI implementation, requiring greater attention, especially in the dynamic landscape of fashion brands and designers. Protecting creative output becomes imperative, requiring a sensitive approach to mitigate potential risks in this area (McKinsey & Company & Business of Fashion, 2023). Another topic that is considered for ethical challenges is transparency. Interviewee 1 shared insights into the difficulty of making data transparent. *'As we are working with other partner platforms giving us access to their data it is quite difficult to state transparency, as we do not know for sure how exactly our partner companies manage the data'* (Interviewee 1). The challenge is to make data privacy and data protection more understandable to the basic user, which may not be the first topic that comes to mind at the C-level. The last topic concerning ethical challenges is the influence on consumers through personalization and ideal targeting. Interviewee 3 highlighted that while AI can make customers' experience better and enhance the process of purchasing and ordering fashion, there is a sustainability concern due to the over-personalization of customers. '*By advertising their ideal needs and wants, AI-driven personalization can lead to overconsumption'* (Interviewee 3). The second dimension of challenges focuses on technical challenges. Data bias is one crucial challenge faced by implementing AI. *'Brands and their partners should carefully construct comprehensive datasets and ensure data teams include diverse backgrounds and perspectives'* (McKinsey & Company & Business of Fashion, 2023). Another identified risk based on the report of McKinsey & Company & Business of Fashion (2023) is the over-reliance on AI models trained solely on historical data, particularly in the context of design. This reliance has the potential to stifle creativity, highlighting the need for a balanced approach that utilizes AI while retaining the innovative human element (McKinsey & Company & Business of Fashion, 2023). Further, building a secure and scalable IT infrastructure emerges as a key requirement. In the aim of utilizing AI for sustainable practices, it is essential to consider the ecological factors associated with its implementation (Boston Consulting Group, 2023). The environmental impact of AI spans multiple dimensions, including greenhouse gas (GHG) emissions, water usage, and waste management, which are crucial determinants. Mitigating and acknowledging these factors is decisive for promoting eco-friendly AI approaches (Boston Consulting Group, 2023). *'Minimizing AI's environmental footprint should become a priority for sustainable AI deployment'* (Interviewee 1). Not only is the implementation and use significant for the responsible use of AI, but also the post-usage activities. The United Nations estimates that globally 53.6 million metric tons of electronic waste was generated in 2019, representing a 21% increase in just five years. And the volume is projected to increase to 74.7 million metric tons by 2030 – representing an approximate doubling of e-waste over a 20-year period (Boston Consulting Group, 2023). Finally, organizations may face challenges in terms of their workforce as a result of the emerging technology. According to McKinsey & Company & Business of Fashion (2023), 73 percent of executives plan to prioritize Gen AI in 2024, but only 5 percent said they are ready to make the most of the technology due to a certain talent gap.

In addition to these representative quotations, the corresponding data and coding structure are shown in Figure 7 below.

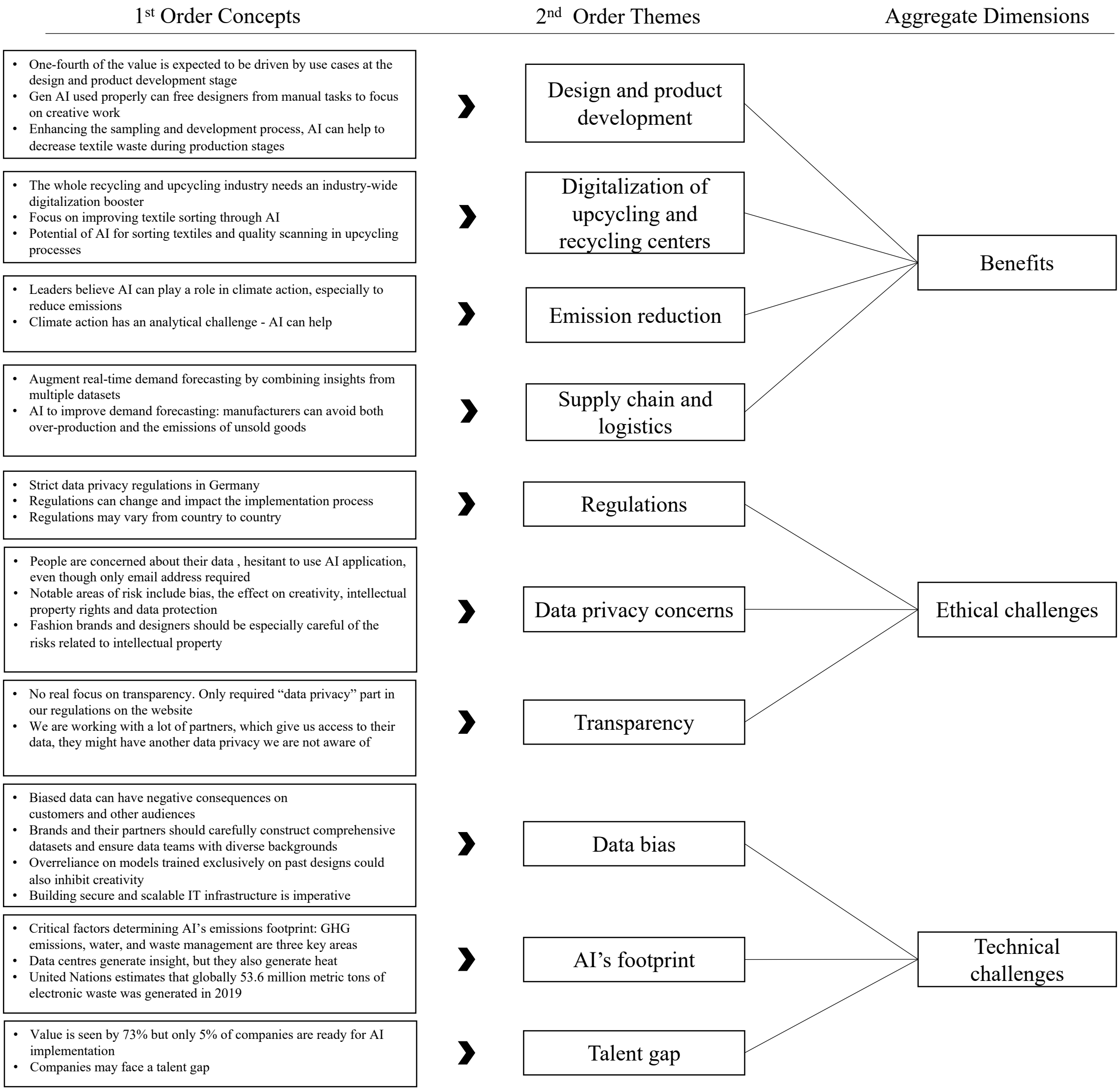

Figure 7: Benefits and challenges of AI deployment

4.4 Two dimensions of AI and sustainability

To conclude the analysis, all findings are put into the dual perspective already presented in Chapter 2.3.2. First, the analysis showcases key areas where AI significantly contributes to sustainable practices in the fashion industry. AI-powered personalization tools enhance shopping experiences by making them more efficient and tailored to individual preferences, thereby reducing waste associated with mass production and returns. Machine learning algorithms are increasingly facilitating the acquisition of pre-owned items, advancing a circular economy within the fashion industry. Additionally, AI technologies are being employed to tackle transparency issues in the multifaceted supply chain of the textile sector, thus ensuring the sourcing of sustainable materials. The adoption of AI at upcycling and recycling centers could transform textile sorting and promote more efficient recycling procedures.

Additionally, AI plays a pivotal role in mitigating emissions by enhancing supply chains and logistics, matching emissions to activities and products along the value chain of businesses, and thereby facilitating the fashion industry's transition towards environmentally conscious operations. The dimension of AI done responsibly stresses the significance of addressing the ethical implications and responsible administration of AI technologies. The analysis acknowledges the rising sustainability and data privacy requisites. The findings address concerns about data privacy and the requirement for increased transparency in the application of AI in the fashion industry. Examining the impact of AI operations, such as greenhouse gas emissions and electronic waste, underscores the need for AI systems that are applied eco-friendly. Moreover, the risk of biased data in AI systems, which can adversely affect customers and stifle creativity, is identified as a significant challenge, requiring observant management and oversight.

By situating AI within these two dimensions, this study emphasizes the importance of utilizing AI for sustainable advancements in fashion and ensuring that these technological integrations are handled with a significant level of ethical, social, and environmental responsibility. This twofold perspective guarantees that AI drives the industry towards innovative and environmentally conscious practices while also adhering to the principles of data integrity, social and ecological sustainability. From all interviews, it was clear that transparency is important to the entrepreneurs, but still, no action is taken towards the explanation of how the software works for each of the cases. This is crucial to attract as many customers as possible and eliminate the barriers of privacy concerns and hesitations towards the technology due to its complexity.

Figure 8 presents an updated version of the matrix originally shown in Figure 4. The changes reflect the findings discovered through the analysis of this dissertation, which have been used to improve the matrix. The data analysis identified several first- and second-order effects which are highlighted using an asterisk symbol.

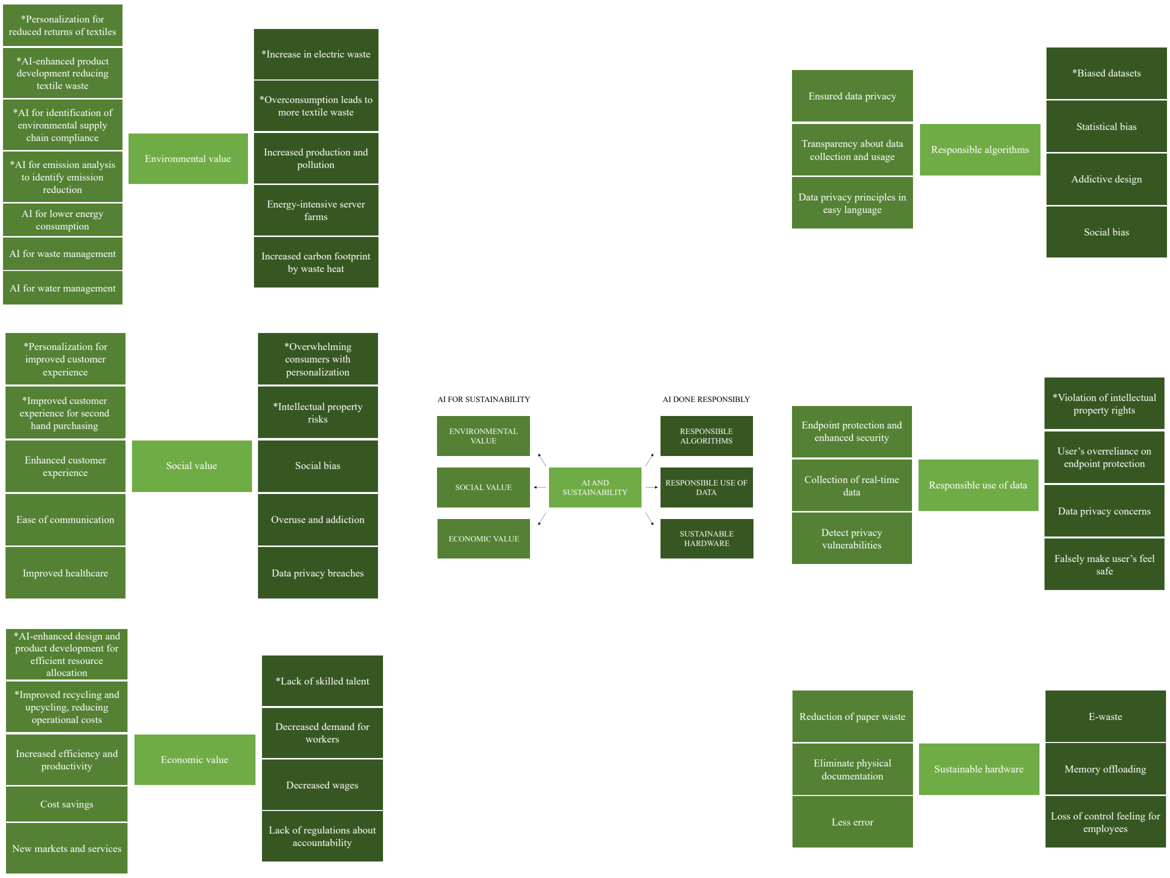

Figure 8: Improved Lotus diagram based on data collection; the new findings are indicated with an asterisk (*).

5 Discussion

This chapter presents the key findings from an extensive data analysis on the integration of AI in the fashion industry. The synthesis of primary and secondary data, including expert interviews, and a review of EU-funded projects and industry reports, reveals that the emerging use of AI in the fashion industry is multifaceted yet encouraging and set to reformulate traditional practices towards sustainability. However, such innovative implementations bring challenges. Research in recent years has highlighted the emerging topic of AI and its potential for sustainable fashion (Bae, 2021; Bolesnikov et al., 2022; Renaningtyas et al., 2023). However, these studies address different research contexts and do not specifically focus on the challenges and risks associated with the implementation of AI. In contrast to those studies, this research shows that responsible deployment of AI technology is vital to address ethical concerns concerning data privacy, transparency, and the ecological consequences of AI systems. It is essential to strike a balance between bold innovation and responsibility, guaranteeing sustainable and ethical harnessing of the advantages of AI as the industry progresses.

5.1 Discussion of the findings

The introduction of AI in the fashion industry marks a significant change toward sustainable practices, a crucial transition supported by the findings of this research. The findings from the qualitative analysis highlight the diverse implications of AI applications, the benefits they bring to sustainability, and the complex challenges they pose. The study identifies three primary applications of AI that are already in use in the fashion industry and are aligned with sustainable practices. First, personalization algorithms represent a significant advancement in aligning consumer behavior with sustainability goals. Consumption can be minimized by personalization regarding the reduction of returns and further textile waste. By leveraging machine learning and browser plug-in technologies for personalized recommendations, AI addresses the core issue of overconsumption, one of the most pressing challenges facing the fashion industry, only showing relevant and suitable products to customers. Therefore, verified by the interviews conducted and secondary data analyzed, AI's ability to tailor the shopping experience to individual lifestyles is not just a convenience, but a strategic tool to reduce textile waste in the future. The facilitation of second-hand shopping through AI reveals an emerging trend towards a circular economy. The research uncovers a notable shift in consumer habits, catalyzed by AI's ability to facilitate the acquisition of second-hand items, thereby extending the lifecycle of garments and reducing the need for new production. Innovations such as the EU-funded FashionBrain project and start-ups like Faircado are crucial in moving the industry towards a demand-driven production model and minimal textile waste through improved circularity. Further, the results highlight the importance of AI in improving the transparency and efficiency of sustainable supply chains. AI can play a crucial role in ensuring the ethical sourcing of materials and verifying sustainable practices in the complex networks of the fashion industry.

Regarding benefits discovered, AI redefines the parameters of design, production, and distribution in the fashion industry. This study evaluates the potential of AI to enhance the design and product development process. By automating repetitive tasks, AI allows humans to concentrate on innovation. AI tools can help reduce textile waste by decreasing the number of prototypes needed for each item produced. With AI technology, products can be designed and tested digitally, thus reducing waste during the production process. In the domain of recycling and upcycling, AI has the potential to digitize and optimize processes, promising a significant overhaul of current practices. The primary data analyzed in this research indicates a need for digital transformation in these centers, which AI is well-positioned to address. Improving the process of up- and recycling enhances the transformation of the fashion industry into a circular economy. This seems to be rather unresearched, according to the interviewees, but it only refers to Germany, excluding insight into other countries in terms of the technological advancement of recycling centers. Lastly, the role of AI in reducing emissions is crucial. AI can analyze large datasets to identify emission patterns and link them to specific tasks in the supply chain, enabling targeted emission reduction efforts. The textile industry produces high emissions that are tied to numerous stages of the supply chain. These stages are difficult for humans to oversee; therefore, AI seems to be a fitting tool.

Despite the promising applications and benefits, the implementation of AI in the fashion industry is facing ethical and technical challenges. The research explored challenges posed by data privacy regulations to technological innovation. First, many consumers are unwilling to share personal data due to privacy concerns. This might be a cultural dilemma, as the entrepreneurs interviewed were all positioned in Germany or Austria. Nevertheless, actors in the industry must help customers overcome their fear and set priority to transparency and education of AI. Further, the research acknowledges the complexity of intellectual property rights in the context of AI, which is of great importance in the fashion industry. The pursuit of transparency, as noted by the interviewees, is a complex challenge beyond mere legal compliance. It is important to ensure clarity in processes and operations and to communicate them to customers in an easily understandable way. Secondly, technical challenges, such as data bias and the environmental impact of AI operations, are significant concerns. Data sets can be biased if the inserted information is not diverse and can lead to falsely guiding users of the software to mistaken decisions. Therefore, data sets must be secure but also rich in variable input. Moreover, to overcome these challenges, a skilled labor force is needed. As stated in the findings, only five percent of companies seem to be ready for the implementation process (McKinsey & Company & Business of Fashion, 2023). This highlights the need for a skilled workforce regarding AI and its consequences. The study reflects on the paradoxical situation where AI, seen as a tool for sustainability in the fashion industry, contributes to environmental degradation through its carbon footprint and e-waste generation. It examines the environmental impact of AI, a topic that has received less attention in current literature. The findings prompt a discussion on the sustainability of technology tools and encourage a reassessment of the environmental footprint of AI in the fashion industry. From the analysis, it is clear that the C-level is aware of AI's footprint, but not much emphasis is put on how to handle this unsustainable part of the technology and how to overcome the negative consequences.

This brings us to the final dimension of results that ultimately answer the research questions proposed for this thesis. To recall the first research question: *What consequences, challenges, or risks may arise from the application of AI in the context of sustainable fashion?* The use of AI in sustainable fashion has both anticipated and unanticipated consequences, as well as numerous challenges and risks. Some consequences have a dual impact, highlighted in different benefits and applications with their controversial risks. Whereas personalization with AI was stated as having a positive impact on fashion sustainability purposes, it cannot be achieved without accessing and analyzing consumer data which can lead to concerns from customers and also to misused insights into consumer behavior. Further, personalization, aiming to do good, can influence consumer behavior and lead to overconsumption due to the highly personalized products which ultimately increases textile waste instead of minimizing it. Therefore, one major challenge is to ensure data privacy and transparency to customers of what data is being used by the software and why. The second two-fold challenge is the implementation of AI for emission reduction. Although AI tools can aid in tracking data along vast supply chains and help reduce emissions at certain parts of the chain, it is important to recall that AI technology itself generates emissions, such as water usage and e-waste. Therefore, when stating the green impact of AI and sustainability, companies must take into account the negative impact generated by AI itself to ensure a transparent and honest sustainability report.

Additionally, other challenges faced in AI implementation are regulations. Regulations can hinder the process of implementation of AI and also might vary across borders. This brings a challenge due to the intensive checking if the technology and its purpose are aligned, nevertheless, regulations are crucial for the responsible usage of AI technology. Regulations are crucial to ensure the sustainable use of data, particularly regarding machine learning, as poorly trained data can lead to biased data sets. Biased data can lead to unintended consequences in terms of customer influence, where a lack of diversity in data sets could harm society. Finally, skilled talent is needed to encounter all the challenges. As reported by the findings, only a small number of companies say they are ready to implement AI. Finally, to overcome these challenges, it is essential for all stakeholders, including industry players, regulators, and technology providers, to collaborate.

Regarding the second research question on the responsible use of existing AI tools, the research discovered the following: it requires a holistic and multi-faceted approach to the responsible use of AI tools and technologies in the context of sustainable fashion. It is crucial to establish a robust data protection framework that recognizes consumer privacy and consent as inviolable. It is equally important to focus on AI awareness initiatives that provide industry professionals and consumers with a nuanced understanding of AI's capabilities and limitations. To maintain consumer trust in the fashion industry, transparency about the role of AI must be promoted. This includes explaining how AI works and its limitations in simple terms and ensuring human oversight of AI outcomes to maintain ethical and creative standards. It is also important to strive for a sustainable use of AI that minimizes environmental impact and is in line with the overarching goals of sustainability. Furthermore, the focus should be on the footprint of AI itself, ensuring the sustainable use of the technology. This comprehensive strategy can ensure that AI tools not only advance the sustainability agenda but also follow the principles of ethical use, data integrity, and environmental stewardship.

This research offers a balanced perspective that considers both the benefits of AI and the need for responsible implementation. The findings suggest a careful approach that utilizes AI's capabilities for sustainability while also managing its ethical implications. The results demonstrate that AI has a dual impact on fashion. On one hand, technology can drive innovation and sustainability, however, it requires transparency, data integrity, and ecological conscientiousness for AI to be beneficial for the industry overall.

5.2 Theoretical contributions

The thesis presents a comprehensive theoretical analysis of the various outcomes and challenges associated with the use of AI in a sustainable fashion. It emphasizes the contradictory nature of AI, which can promote efficiency and consumer-focused innovation, while at the same time raising ethical and operational dilemmas, particularly in the areas of data privacy and transparency. These contributions were based on a thorough review and analysis of existing literature in addition to real-life examples based on expert interviews to advance the knowledge and understanding of the research topic. This study provides new insights into the relationship between sustainable fashion, data ethics, and sustainability in the context of AI and fashion. It highlights the benefits while also identifying significant challenges, including infrastructural and cultural barriers to adoption and unanticipated environmental impacts. The research presents AI as having both positive and negative effects on sustainability in the fashion industry. Therefore, a more nuanced and responsible approach to its integration is necessary to ensure eco-friendly practices. Further, the matrix presented in Chapter 4 (Figure 8) shows the topics related to sustainable fashion and AI, according to the industry experts interviewed. The results indicate themes that are consistent with and supportive of the literature review, while also highlighting less explored areas that are relevant to the ethical implementation of AI for sustainability in the fashion industry.

5.3 Managerial contributions

The findings suggest that AI is a promising tool for managers, but caution must be exercised. Managers should not only embrace AI for its efficiencies but also remain vigilant about its tendency to violate consumer privacy and potentially distort consumption patterns. The insights highlight the need for proactive consumer education on AI and the importance of maintaining trust and ethical standards through transparent AI-driven processes. The study also provides evidence-based recommendations for fashion industry leaders to consider the full environmental footprint of AI technologies to inform strategic decision-making for a truly sustainable business model. Finally, managers need to emphasize the significance of a highly skilled workforce to ensure proper implementation by technically proficient employees and adequate compliance with sustainability targets and regulations. A framework for ethical AI implementation is provided in the appendix (Appendix 2). This framework was inspired by previous research focusing on how to foster digital sustainability for a better future (Binder & Wade, 2023).

5.4 Limitations

Among the theoretical research limitations of this study is the novelty of the topic. AI is a relatively new topic, and its application to the fashion industry is even more so. Regarding empirical research limitations, only a limited number of companies and start-ups have implemented AI technology in the fashion sector. This is because it is a very specific and emerging topic Further, the lack of responsiveness and availability of these companies for interviews was a limitation of this study. In addition, the reliance on qualitative findings from a specific cultural and regulatory context – primarily Germany – may not fully reflect the global complexity associated with AI in fashion sustainability.

5.5 Recommendations for future research

Future research should expand the investigation of AI's dual role in sustainability to encompass a more diverse cultural and regulatory environment. Additionally, mixed methods should be employed to quantify the extent of AI's intended and unintended impact on consumer behavior and the environment. Furthermore, examining the lifecycle of AI from development to disposal could provide a comprehensive overview of its environmental footprint.

6 References

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7 Appendix

Appendix 1

Sustainable Development Goals, United Nations (2015)

Appendix 2

Managerial Guide to AI-Driven, Responsible Fashion Sustainability

Sustainability Challenge / Opportunity	– Hidden environmental violations of AI – Over-personalization leading to over-consumption – Protecting intellectual property rights in AI design – Ethical considerations: data transparency and privacy – Talent gap regarding sustainable AI implementation	– Technical risks: data bias and reliance on historical data – AI-driven personalization to reduce overconsumption – Improving the second-hand market experience with AI – AI in sustainable supply chain management
Responsible use of AI	– Check for a diverse dataset – Minimize social and statistical bias – Ensure transparency regarding data usage – Minimize e-waste through sustainable hardware	– Communicate data security in user-friendly language – Ensure intellectual property rights – Consider the overall footprint of AI technology
Digital enablers	– AI and Machine Learning for Shopping Personalization – Browser plug-ins for suggestions – AI-powered supply chain risk analysis platforms	– AI to reduce prototype waste through product development – 3D avatars for fitting and customization
Digital Sustainability Outcome	– Reduce textile waste with AI – Optimized recycling/upcycling through AI	– AI-powered insights for emissions reduction – Improved supply chain and logistics demand forecasting