The Impact of Artificial Intelligence on Circular Value Creation for Sustainable Development Goals

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Abstract: Circular Economy (CE) business models provide solutions for sustainable development goals by closing, slowing, intensifying, de-materializing, and narrowing resource loops. Addressing CE needs a strategic redefinition of the way companies are creating and capturing value, which leads in designing a new value creation system and innovative business models. For a full circular value creation, circular products should be designed and developed specifically for repair, refurbishing and remanufacturing purposes to close the loop. Hence, companies need to radically change their business models and the way they create value towards more innovative solutions based on CE strategies. However, implementation of circular business models in business practices has not been widely utilized and requires fundamental changes within the value chain. In a successful circular value creation, a higher degree of transparency and high-quality data for the entire value chain is required for further development of the products and processes, hence enabling design optimization and management of supply chain. Recent debates show that Artificial intelligence (AI) can be considered as an enabler of CE to help companies in innovating circular business models. Different applications of AI such as machine learning, automation and robotics, and machine visions have the capability of collecting, analysing and storing digital data. AI-enhanced products and services can tackle environmental problems through independent interactions with their surroundings and self-learning capabilities, which results in improved environmental performance characteristics. In this chapter, we identify the role of AI in circular value creation for sustainable development goals.

Keywords: Artificial Intelligence, Sustainable Development Goals, Business model, Circular Economy, Industry 4.0, Value Creation

1 Introduction

Sustainability has been discussed widely since the topic was identified by Brundtland in 1987 (Commission on Environment and Development 1987). To promote sustainable development approach, United Nation established 17 Sustainable Development Goals (SDGs) in 2015 as a universal action to stop poverty, protect the planet, and increase peace and prosperity (United Nations 2015). However, despite the significant efforts made by different nations, the successful achievement of goals objective is often hampered by the economic challenges and profitability issues faced by businesses. The concept of CE, has gained attention of researchers, policymakers, and various organizations worldwide as a way of promoting SDGs while enhancing economic development (EM Foundation 2015; Geissdoerfer et al. 2017). The CE model is an alternative to a traditional linear system, which is responsible for current environmental problems, resource depletion and climate change. CE practices contribute directly to achieving Goal 12 of SDGs (ensure sustainable consumption and production patterns). Integration of CE principles for SDG 12 requires an early-stage consideration in product design and development processes.

CE oriented business models are built on the principles of keeping products and materials in the economy as long as possible with highest value retention. Since the main aim of CE models is to eliminate the use of finite material and energy resources in the entire lifecycle of the products and materials, CE models are seen as a potential driver in SDG 12. In CE the value creation is decoupled from consuming limited resources by leveraging sets of regenerative, restorative and efficient productivity-oriented strategies which keeps products, components and materials for a longer time with highest possible value (Ellen MacArthur Foundation 2013; Lieder and Rashid 2016). According to Bressanelli et al., (Bressanelli et al. 2018), implementing CE strategies creates a net benefit of €1.8 trillion by 2030 in Europe alone while creating new jobs, stimulating innovation, as well as increasing considerable environmental benefits. CE is the core in the UN SDGs (Schroeder, Anggraeni, and Weber 2019) which can be achieved through reducing structural waste which leads to decrease the demand for limited virgin material and transformation from consumption of the natural resources that still have a useful life, but would otherwise be sent to landfill (Hysa et al. 2020). Despite of all the benefits CE can bring to the environment, society and government (ESG), the adoption of CE strategies

and how organizations create, deliver, and capture value, in CE is still uncertain and only minor improvements have been recognized in decoupling from linear resource consumption (Whicher et al. 2018) .

The recent report by Sitra (2021) highlights the core role of data in transition towards CE. In a CE, data on resource flows, location tracking, monitoring condition and quality, real-time data gathering, processing of input-output flows, precise prediction, lower production downtime, and optimization of energy consumption are essential. (Hughes et al. 2021). CE requires a strong integration and connection of the value chain which brings data economy at the center when considering development of CE solutions. Since Industry 4.0 technologies are capable of collecting, storing, analysing and processing large amount of data, they can position such data and information flows to enable resource and energy efficiency towards a more sustainable CE (Ellen MacArthur Foundation 2019; Kristoffersen et al. 2020; Ramadoss, Alam, and Seeram 2018; Lacy, Long, and Spindler 2020). Industry 4.0 technologies such as Internet of Things (IoT), Artificial Intelligence (AI), and big data are considered as digital technologies which are enablers of CE. According to Yoo *et al.* (2010), Industry 4.0 technologies share three essential characteristics which distinct digital technologies from other technologies are: 1) that they are programmable, 2) creating, sharing and capturing data as a homogeneous source, and 3) reinforcing each other by self-referencing. Such technologies have critical roles in CE by creating precise data for improving resource management and efficient decision-making, as well as tracking the flow of products, components and materials throughout all the stages of industrial life cycle (Antikainen, Uusitalo, and Kivikytö-Reponen 2018; Nascimento et al. 2019; Lacy, Long, and Spindler 2020; Bressanelli et al. 2018).

However, there is still a lack of concrete guidance on how to leverage Industry 4.0 technologies to support CE strategies which offer novel opportunities for business leaders (Kristoffersen et al. 2020). The challenge of moving towards a full CE is substantial and the world is only at the early stages, for which Industry 4.0 technologies can maximize the transformation of business models, products and services for a more durable and sustainable outcomes and help organizations to overcome challenges and simultaneously remain competitive in sustainability aspects in business. Hence, the primary objective of this work is to investigate how CE and digitalisation affect business model innovation. The remainder of this book chapter is organized as follows: next sections respectively investigate the key role of AI in CE, and how AI can be utilized to leverage circular value creation with supporting business cases.

2 AI in CE

Industry 4.0 technologies and its supporting systems provide integrated tools that can help tackle these issues by providing improved “any-time,” “any-where” for “any-thing,” tracking and insights of their business processes (Lee 2018). This has the potential to transform how businesses implement their sustainability strategies. Consequently, companies are increasingly developing new business models that focus on reuse, repair and remanufacturing of their products and services (Melander and Pazirandeh 2019). The combination of digital transformation, the circular economy and business model innovation present a huge opportunity for businesses to create and capture new value. Digital technologies can play role in three different CE business model innovation: 1) As tools to support identify and implement business models related to strategies, patterns, and components (Lewandowski 2016; Nancy M.P. Bocken et al. 2016), 2) To support the implementation of managerial practices for CE transitions in companies (Centobelli et al. 2020; Ünal, Urbinati, and Chiaroni 2019), 3) They offer service-based business models in which a product is replaced by a service supported by machine intelligence (Alcayaga, Wiener, and Hansen 2019; Tukker 2015). According to (H. Berg et al. 2020) the digital technologies can enable CE as follows:

- Digital technologies which enable more efficient and circular manufacturing processes of materials and products such as intelligent design, sensor technologies, machine learning, robotics, etc.
- Digital technologies which enable tracking and tracing the products and components, optimization of value chain, product and service development, increasing reuse, repair and refurbishment such as IoT, blockchain, etc.
- Digital technologies which connect consumers and producers enable service development and dematerialization such as AI-powered platforms.

AI as one of the Industry 4.0 technologies describe self-learning and self-correcting computational processes that mimic human-like reasoning and problem-solving (Kok et al. 2009). AI techniques respond to their environment through capabilities cognitive and intelligent capabilities (Townsend and Hunt 2019). The main benefit of AI techniques lies in their capacity to collect, process, and analyse large quantities of data in short and up to real-time from various sources (Mühlroth and Grottke 2020). Apart from handling superior quantities of data, AI techniques detect and unveils patterns that were not visible before, to suggest relations humans are not aware of. Furthermore, AI techniques automatically deduct

consequences based on its analysis and matches data input to a connected task (Balasubramanian, Ye, and Xu 2020). These capacities make use cases in the context of CE evident. AI techniques can support circularity of the whole value chain by consumption and demand prediction, smart product design, enabling/enhancing remanufacturing processes by remote monitoring (Ghoreishi and Happonen 2020b). AI techniques can enable CE opportunities by boosting circular product design and development, optimizing infrastructure to ensure the flows of such products, and operating circular business models (Ellen MacArthur Foundation 2019). According to Ghoreishi and Happonen (2020a), AI can enhance the value of recycled and recovered materials by smart waste sorting. AI based platforms can enable product and material sharing which enhances extension of products lifecycle (Waheed and Khalid 2019). Different roles of AI techniques in different cycles of CE and customer support phase are illustrated in Figure 1.

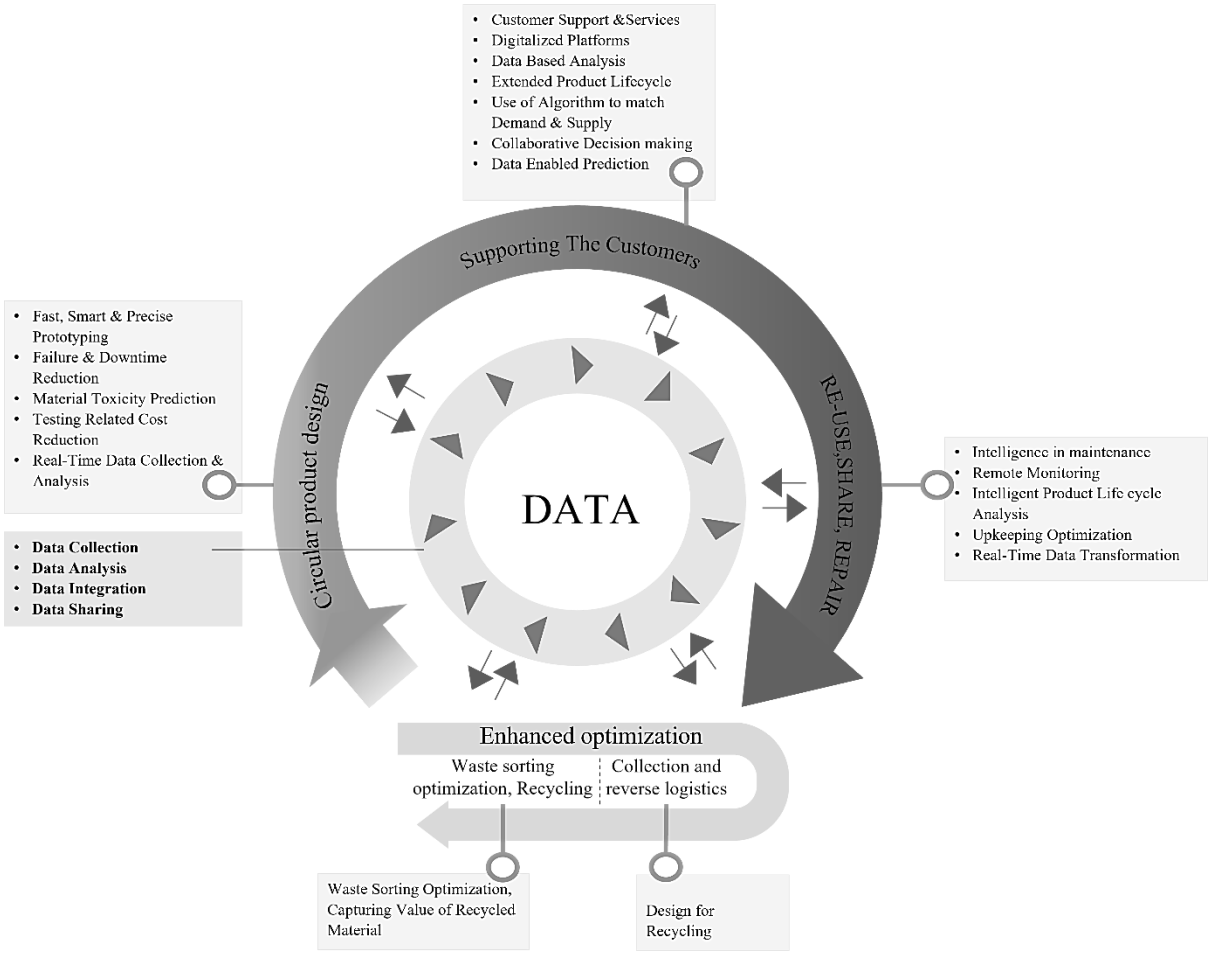

Figure 1. Role of AI in CE (based on Ghoreishi and Happonen 2020 a)

AI can operate circular business models by introducing new business propositions such as asset sharing, product as a service, potentials to cut inventory levels, and AI-based platform.

Dynamic pricing and matching algorithms can enable the sharing and access business models whereas in revers logistics and remanufacturing requires a powerful AI-based analytical model to collect customer and product data and transfer it as a feasible decision-making model (Ellen MacArthur Foundation 2019).

An example of utilization of AI circular business model for AI-based platform is Israeli startup Algoretail (2021) which uses machine learning to automate grocery retail stocking procedures from the supplier onto to the store shelves. The automated AI-Powered replenishment tool, Algoretail IO, offers a data-driven sales forecasting which helps in reducing waste of fresh food items. In addition, Algoretail IO provides granular reporting with graphic representations of insights along with customizable alerts regarding products that are about to expire. This way by utilizing AI, the startup helps groceries in reducing 35% waste reduction as well as 15% increase in their net profit.

As an example of product as a service business model is the American startup Smarter Sorting (2021), which develops a cloud-based Software-as-a-Service (SaaS) for waste management platform for retailers. AI is utilized to provide real-time data and up-to-date information on inventories, such as the attributes of a product and its packaging. This allows retailers to better understand which products are eligible for recycling, which are suitable for donations, and so on. These insights cut waste volumes and reduce disposal costs. In addition, full transparency into the data and trends driving the retail operations, ensuring compliance, operational efficiency is provided by store and item level analytics which increases business success.

3 Circular value creation

Since circularity aims to maintain the functionality of the materials and components at their maximum level as long as possible throughout their entire life cycle, material stocks and flows are required to be managed in a sustainable way. To incorporate sustainability and circularity into products, product designers require the right tools, including measurement frameworks and tools that integrate metrics and indicators; are essential to maximize value creation from products and materials (M. R. Van den Berg and Bakker 2015). Most quantitative sustainability tools which are currently utilized by businesses are based on Life Cycle Assessment (LCA), in which the environmental impacts of components and materials are assessed along parts of its life cycle (Ramani et al. 2010). Although life cycle assessment, life cycle inventory, and the current methods of measuring product sustainability are useful, they are more suitable for post-design evaluations of completed products (Buddhika M. Hapuwatte and Jawahir 2019). A

model-based methodology is required in the design phase to predict how sustainability decisions will affect the product during its whole lifecycle (B. M. Hapuwatte, Badurdeen, and Jawahir 2017; Buddhika M. Hapuwatte and Jawahir 2019). When designing and developing new product, once the specifications of the products are made, minor changes can be made since resources, infrastructures, and activities have been allocated to a certain design (N. M.P. Bocken, Farracho, et al. 2014). Van den Berg and Bakke (M. R. Van den Berg and Bakker 2015) distinguish the key features of circular products as "future proof, disassembly, maintenance, remake and recycling".

To achieve circular value creation, organizations need to design strategies which support value in circular business model such as (1) utilizing material resources and energy efficiently (narrowing the loop), (2) Produce products that are natural, reliable, durable, and longer-lasting, and focus on life extension through the standardization and compatibility, upgradability and adaptability and dis- reassembly of its individual physical components (slowing the loop), (3) Reuse products, components and materials through dis – reassembly principles, design for recycling, design for remanufacturing, design for environment and factoring in their technological and biological cycles (closing the loop), and use non-toxic materials and renewable energies (regenerate the loop) (N. M.P. Bocken, Farracho, et al. 2014).

Value creation in CE occurs through the recovery of returned products within the supply chain in closing the loop (Schenkel et al. 2015). Therefore, it is essential to develop products in a way that the materials can remain in the loop and be continuously and safely recycled into raw materials for manufacturing new products (Nancy M.P. Bocken et al. 2016). In this way by adding value from the forward- and reverse supply chain, CE business models can leverage the process of circular value creation for costumers, environment, economy, and information value. For this reason, support of all the partners within the supply chains in developing awareness and new skills is essential in rendering business models for circular value creation (Ünal, Urbinati, and Chiaroni 2019).

For a continuous flow of resources in CE, firms need to radically change their business model for innovative product design. Based on assertions, design principles for sustainability, circular design should focus on circular supplies, resource conservation, multiple cycles, long-life use and system change. This implies firms to innovate their business model strategies to create and capture new value and develop competitive advantages from CE and circular product design (Linder and Williander 2017; Urbinati, Chiaroni, and Chiesa 2017; Lin 2018). For instance,

‘slowing the loops’ strategies can allow firms to encourage their customers to be sufficient through reducing their consumption habits. Whilst extending and exploiting their products residual value. Examples include the leasing of products, car sharing, and clothes return initiatives. Whilst ‘closing the loops’ strategies seek to extend resource value through exploiting their residual value, and industrial symbiosis that use residual outputs from one process. Examples include the collection, supply and recycling of products (N. M.P. Bocken, Short, et al. 2014).

According to Mishra *et al* (2018), opportunities for circular value creation can be analysed based on four broad archetypes as follows:

- “Inner value creation loops, which concerns maintaining of the integrity of products as highest level through service and maintenance.
- Extending value creation loops, which concerns the use of products and materials for longer time.
- Cascading value creation loops, which concerns cascading use in adjacent value chains (where the costs of reused products and materials are lower or have superior value compared to virgin or non-renewable materials).
- Pure value creation loops, which concerns the creation of pure, high-quality feedstock at the outset (avoiding contamination and toxicity to allow for reuse and cost avoidance of clean up or purification)”.

Implementing these archetypes in specific business models take many forms such as performance and servitisation-based models, product-service systems, and collaborative consumption (Ghisellini, Cialani, and Ulgiati 2016). Considering CE-oriented business models add uncertainty and complexities to conventional business models, the addition of reverse logistics, the return of resources at what time, quantity, and quality, as well as customer perceptions would be useful in developing a CBM (N. M.P. Bocken, Schuit, and Kraaijenhagen 2018). According to Urbinati et al. (2017), circular principles can be integrated into business models in three ways: downstream circular (new schemes, customer interfaces make alternatives for value), upstream circular (change the systems for value creation), or fully circular (a combination of downstream and upstream principles). In the context of current business models, AI techniques have great potential to create circular value (Ellen MacArthur Foundation 2019).

4 AI and Circular value creation

AI is one the key enablers of circular business models that can enhance and accelerate CE through product design and development processes which are assisted by machine learning for faster testing and prototyping (Ellen MacArthur Foundation 2019). AI techniques can integrate real-time and historical data from products and users which helps to increase circulation of the products for a longer period of time by predicting precise price and demand, maintenance services and smart inventory management. Blunck and Werthmann (2017) state that assessing the demand through AI enables optimized decisions regarding material reusability. EMF (2019) emphasize this point further, affirming that AI supports CE implementation by improving reverse logistics and associated decision-making processes in sorting and disassembling and by utilizing both historical and real-time data to predict demand and thus, optimize inventory and production management (Ellen MacArthur Foundation 2019). Focusing on the CE micro level which involves companies, products and consumers, the role of AI can be analysed based on the Regenerative, Share, Optimize, Loop, Virtualise, Exchange (ReSOLVE) framework (Jabbour et al. 2018) presented in Table 1.

Table 1. Capabilities of AI based on ReSOLVE framework in CE principles (developed by authors)

Framework component	Circular value creation initiatives	AI techniques
Regenerate	Return recovered materials and resources	AI-powered robots, AI-based software
Share	Share assets, Reuse second-hand products, Maintenance services	AI- based platforms, machine learning,
Optimize	Digitally connected supply chain, digital product passport	AI-based platforms, online databases
Loop	Remanufacturing products or components, Recycling and upcycling products	Robotics, Machine vision, Machine learning
Virtualise	Dematerialize indirectly (e.g. online shops)	Intelligent automation platforms
Exchange	Intelligent design and prototyping	Machine learning and algorithms

Recent models of “human- only”, “human-machine”, and “machine-only” decision-making are shifting the way organizations learned and evolved innovation based on wide range of AI applications (Daugherty and Wilson 2018). According to Brem *et al* (2021), AI has two main roles in transforming innovation as originator and facilitator of innovation. As an originator,

AI shapes the creation of products and processes and is the starting point for innovation where the product portfolio is based on software and company maturity is emerging. As a facilitator, AI augments existing products and processes and is the starting point for transformation where the product portfolio is based on hardware and company maturity is established.

AI driven business models can play a significant role in achieving SDGs through their ability to make alternative ownership options a reality (Baines et al., 2007; Schmidt et al., 2016), that focus on providing access to intangible outcome-based services or the combination of tangible products and intangible services such as use- or result-orientated business models, rather than product-orientated models (Yang and Evans, 2019). Most of these offerings can be categorized into the product-oriented (PO), use-oriented (UO), and result oriented (RO) business models, which are considered as the main types of product/service business models (Reim, Parida, and Örtqvist 2015). In these scenarios, main focus of PO is to sell a tangible product with additional services. The focus also remains on consumer ownership and the consumption of resources similar to in the past. As a consequence, PO models are considered to the contribute the less to achieving SDGs. Alternatively, in UO and RO we see a shift towards more sustainable consumption through alternative business models that focus on the 'stewardship' of tangible and intangible product-services. Specifically, in a UO model whilst the product is still central to an offering, rather than selling it to the customer, the access and usage of the product is guaranteed by the provider for the specific period of time and is subscription based paid by the user. Further, in RO result is what the customer pays for rather than a product and the supplier is full responsible for the result. Table 2. provides a comparison of three different business model in terms of value creation, value delivery and value capturing.

Table 2. Comparison of AI facilitated SDG high-level business model categories in terms of value creation, value delivery and value capturing (Source: Reim, Parida, and Örtqvist (2015))

	Product-oriented	**Use-oriented**	**Result-oriented**
Value creation	Provider is responsible for agreed services	Provider takes responsibility of the usability of products and services	Provider takes responsibility for delivering results
Value delivery	Provider is responsible for selling and providing services products	Provider guarantees the usability of the physical product along with services	Provider is responsible for delivering results
Value capturing	Customer pays for physical product and for the performed services	Customer can make continuous payments over time (e.g., leasing)	Customer payments are based on outcome units; that is, they pay for the result

To illustrate the role of AI in different business models and their value provision process, we selected three cases, each presenting one business model type. For PO model we selected a

textile industry company Unspun. Unspun is a textile industry company that utilizes 3D body scanning to produce sustainable tailormade jeans for customers. The example case for UO model is Naava, a company which offers air purifying design plant walls for office spaces. As a RO model we selected company called Augury. Augury provides machine health solutions for industry. The value process of the cases is analysed in Table 3 and the role of AI is highlighted in each phase.

Table 3. Case example analysis based on different roles of AI in circular value creation (developed by authors)

	Product-oriented (Unspun)	**Use-oriented (Naava)**	**Result-oriented (Augury)**
Value creation	Aims to reduce waste by offering sustainable jeans that are tailored individually for perfect fit. The Role of AI: Data collection. The customers' body is scanned by AI powered 3D scanners.	Offers smart wall of plants that constantly purifies indoor air and provides a constant stream of clean air. The Role of AI: Remote condition management system that keeps the plants in optimum condition by connecting the sensor data of airflow, water and light and e.g., adopting to weather data.	Offers an asset management and maintenance service for industrial machines. The Role of AI: The system uses sensors and AI for monitoring and detecting mechanical errors in machines and to provide preventive maintenance.
Value delivery	The body scan data is turned to digital jeans. These are then manufactured by robotics powered sewing machines. The Role of AI: The AI algorithms are used to digitally design the jeans around customers 3D avatar.	An operating system for remote management and a full maintenance service. The Role of AI: Full operation and maintenance with automated AI operated system.	The sensors collect data from the machines. The data is stored into cloud and analysed for problems to prevent failures and manage the maintenance. The Role of AI: The sensors measure the vibrations, magnetisms and temperatures in real time. AI analyses the abnormalities in the data and provides instructions and prioritized action points.
Value capture	Order delivery model. The technology enables a zero-inventory model and reduces waste. The Role of AI: AI enables the made-to-order model.	Monthly service fee The Role of AI: Optimize the service and maintenance operating costs for provider.	End-to-end service with a warranty for broken machines. The Role of AI: Provides accurate and reliable information on machine health.

AI is utilized for circular value creation in different ways in each case. In PO case Unspun, the role of AI in value creation is to scan and collect accurate data of customers body to enable the tailor-made jeans. There is an option of a remote measurement. In both UO and RO cases the

main role of AI is in the remote condition monitoring. In UO case Naava, AI keeps the plant wall operating in optimum way and automatically, so that the customer doesn't have to. In RO case Augury, AI "listens" to the machines data to detect anomalies and to preventatively inform the customer of potential failures. The aim is to eliminate downtime and to optimize the production. Moreover, the role of AI in value delivery of the cases varies. In the PO case Unspun, the role of AI is to design a 3D avatar of the customers data points and utilize this in fitting the jeans as well as optimizing the production. In UO case Naava, AI has the most central role among these cases. AI handles automatically the remote monitoring and remote operation of the plant wall and notifies the maintenance teams automatically. In Augury's RO model, AI based remote monitoring and preventative maintenance are the key roles, but AI does not handle the operation. The value capture model and the role of AI in it differs most among the cases. In Unspun's PO model, the value capture model is the basic order-delivery model, for which AI is the key enabler, whereas in Naava's UO model the value capture model is a product-as-a-service leasing model (the wall can also be purchased) with a monthly fee. The major role of AI in this case relates to optimizing the providers maintenance costs. In the RO case Augury, the role of AI is the biggest in value capture. The unplanned downtime is very costly in manufacturing and to prevent this, the companies are willing to pay. Augury's AI technology is very accurate and constantly learns from all their cases which optimizes prediction and prevention of downtimes. The company also provide an insurance for the customers in case that a machine gets broken even though using the service.

DISCUSSIONS

Technologies like AI and its supporting systems facilitate the transition towards more sustainability-oriented business models by bringing together suppliers and demanders of goods, services as well as environmental and societal factors which are challenging traditional business model thinking (Alstyne, Parker, and Choudary 2016). Furthermore, business models in CE and sharing economy model are different from traditional and current business thinking. Such trends aim to change existing business models towards new ways of producing, transporting, consuming, and reusing materials, components and products/services. Smarter business models will enable higher efficiency of resource consumption as well as customization of products/services in a way that can improve the offering to customers while reducing their environmental footprint, and influencing the positive behavior of network partners (Bocken, Short, Rana, & Evans, 2014; Jørgensen et al., 2018). This can result in

positive sustainability effects through an enhanced product usage and replacing products with new, higher efficient, more innovative products and materials (Sundin and Bras 2005). Therefore, the combination of such product and service solutions, will offer benefits of offering united product and service solutions have economic, social, and environmental effects as digital platform ecosystems and users move from the principle's ownership to stewardship, which are increasingly meet by intangible services rather than tangible products as in the past (Reim, Parida, and Örtqvist 2015). In practice, the shift to these business models enabled by AI techniques can contribute to product life extension through service, remote and predictive maintenance, and repair that have the potential to reduce the environmental impact in a product's lifecycle. In addition, it has the potential of slowing resource loops by extending the value chain of products and materials for longer periods and to recover raw materials after the lifetime of the products for their reuse (N. M.P. Bocken and Short 2016) through the development of take-back systems, refurbishment, design for circularity and recycling (Kristensen and Remmen 2019). AI capabilities to collect and interpret highly personalized data generated through user interactions with their product(s) rather than generalized pictures as was the norm in the past, can provide dual benefits in this sense through its ability to enhance user experience through the supply of product and services that satisfy individual consumption behaviours, including those associated with sustainability. Whilst allowing them to develop their prediction capabilities that impact both their internal and external processes e.g., product and/or service innovation (Frank et al. 2019; Karhu and Ritala 2021).

Building upon the theme of digital enhancement, AI techniques (Breidbach, Brodie, and Hollebeek 2014; Li and Found 2017; Storbacka et al. 2016) that influence the development of a product bring together a network of interconnected actors and objects that work in coopetition to create and capture mutual value (Akaka and Vargo 2015; Vargo and Lusch 2004). This can result in the key challenge of conceptualizing and capturing of these interactions and engagements across numerous technological contexts (Breidbach and Brodie 2017; Li and Found 2017). Emergent technologies like AI and connected technologies, including IoT and smart sensors, can facilitate this through their ability to automatically and autonomously collect, analysis, interpret and integrate elements from the physical world and computer/internet-based systems into their offerings. This can result in improvements in efficiency, accuracy, and economic benefits for providers of products and services, and their consumers through both party's ability to provide and collect data anytime, anywhere on anything. Helping providers to continuously improve product design, including the ability to

enhance its durability. Enabling the components of a tangible product to remain in use longer leading to higher return on investment and enhancing user experience and engagement. AI supported by IoT technologies and smart sensors, can enhance this further through its ability to allow digital platform ecosystems to monitor a products components condition, location, and status which supports product sharing between multiple users. In turn, these outcomes can be used to improve strategies of recovery such as remanufacturing, reusing and recycling of physical items (Alcayaga, Wiener, and Hansen 2019), and where intangible services can provide a viable alternative to tangible products. This enables providers and their complementor/supply networks to make precise, estimations on physical elements of a product's useful lifecycle, supports decisions on optimal remanufacturing time of a certain product and can improve the profitability of remanufacturing activities(Ingemarsdotter, Jamsin, and Balkenende 2020).This is achieved through the ability to make better assessments of products condition and take preventative actions to extend its lifecycle.

CONCLUSION

In this chapter we highlighted the important role of AI in circular value creation for SDGs. Adopting CE requires companies to initiate and develop business models based on circular value creation principles such as remanufacture, dematerialization, sharing, and servitization. This can be best enabled and achieved by utilizing disruptive technologies such as AI. Different applications of AI can be utilized in different circular value creation and accelerate the transition towards a successful CE. A critical enabler in these processes is the business model innovation built upon the principles of CE and SDG which focus on reuse, repair and remanufacturing of products (Mont, Dalhammar, and Jacobsson 2006) based upon the principles of collaboration /coopetition with their customers, partners/competitors, and suppliers using AI technologies. This can result in different levels of environmental advantages through new products (Melander and Pazirandeh 2019) including higher energy efficiency, lower material consumption, increase of pure materials, lower fuel consumption, preventing toxic components and materials, use of digitalisation in predicting enhanced usage and integration of more environmentally friendly materials. Repair, maintenance, reuse, and remanufacturing products are the ways through which companies are able to enhance resource utilization and to prolong the lifetime of product (Mont, Dalhammar, and Jacobsson 2006; Östlin, Sundin, and Björkman 2009). For a successful remanufacturing, access to products that can be remanufactured is important. For example, through take-back agreements with

customers (Östlin, Sundin, and Björkman 2009). These kind of agreements can enable recycling, where companies are responsible for the end of life of products (Smith and Crotty 2008). In addition, collaboration with different partners within a company's ecosystem can lead to saving raw material, improving waste disposal, limiting pollutions, reducing energy consumption, as well as packing and transportation (Manzini and Vezzoli 2003).

Since data plays the core role in circular value creation, companies that integrate digital technologies such AI and IoT into all principles of CE can build more efficient business models and consequently higher efficiency in resource and material usage with lower costs. Therefore, one of the future research focuses recommended by this chapter is assessing the role of Artificial Intelligence of Things (AIoT) in circular value creation for SDFGs. IoT sensors can collect and transfer precise data on products status and conditions which can be further process and anlyse faster with AI. In an IoT enhanced environment, AI can close the loops of products and materials, lowers energy and resource usage, therefore enhances circular value creation. However, despite all the potentials offered by digital technologies in creating circular values and SDGs, it needs to be stated that such technologies can simultaneously lead to unsustainable practices. As these practices are significantly technologically-driven and revenue-driven following linear production and consumption levels, the introduction of smart technologies and automation may lead to increased consumption behavior, energy use and environmental impacts as well. Industry 4.0 technologies can lead to huge environmental footprint and energy intensity. Therefore, the environmental and societal impacts of the digital technologies themselves must be carefully assessed, and circular principles must be embedded in the digital products, as a condition to their deployment in the economy, to ensure a global net positive balance. Digitalisation can use circular economy as a guiding principle, a target to reach a sustainable endpoint. On the other hand, the digital technologies are dependent on the availability of critical raw materials. Therefore, the challenge will be to develop the digital circular economy in such a way that the digital technologies compensate for the need for materials that they are made of. This is a strong demand to introduce principles of dematerialization, lifetime extension and recycling into the digital systems that build the circular economy.

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