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# NFT-ENRICHED SMART CONTRACTS FOR SMART CIRCULAR ECONOMY MODELS

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**Abstract.** A smart contract is an electronic transaction protocol intended to digitally facilitate, verify, or enforce the execution of the terms of underlying legal agreements. Thus, by following the traditional perception, smart contracts target reducing transaction costs, including arbitration and enforcement costs, by realizing trackable and irreversible transactions using blockchain technology for distributed databases. However, the potential of smart contracts goes far beyond cost reductions by facilitating the entrepreneurial collaboration of cross-organizational business processes. Industry 4.0 aims to create smart supply chains. Smart contracts and Non-Fungible Token (NFT) solutions can realize new smart business models in the circular economy. The recent case study from the automobile industry demonstrates how using NFT technology in the form of a digital certificate can become an integral part of smart product lifecycle management in the frame of a circular economy integrating innovative business models with smart service design concepts. By doing so, the use of NFT paves the way for dynamic and adaptable supply chains, evolving needs of stakeholders towards a sustainable and circular economy. The authors participated in research projects related to smart supply chains and circular economy. Thus, the paper discusses the question of how and to what extent smart contracting, blockchain technology, NFT solutions, and Service Design can facilitate the implementation of smart business models in the context of the circular economy. The research is based on expert interviews, surveys, and case studies from EU projects focusing on the Baltic Sea Region.

**Keywords:** smart contracts; Non-Fungible Token (NFT); smart supply chains; service design; business models; circular economy

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**JEL Classifications:** O33, L86, Q55, L23, M15, L62.

**Additional disciplines:** law; information and communication; ecology and environment; transport engineering; environmental engineering; informatics

## 1. Introduction

The classical pathway of mass production has been known as a linear model where products that reach the final stage of their lifecycle are trashed so that the remaining resources are wasted, creating an imbalance between resource supply and goods demand (Murray et al., 2017). With the current trend in production and consumption rate, sustaining development and providing future generations with resources will not be possible. Overcoming the contradiction between the need for economic growth and the necessity for accomplishing environmental sustainability is thus one of the most compelling issues of our time (Hobson & Lynch, 2016; Marques et al., 2018; Zecca et al., 2023).

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Catering the need for an alternative model of sustainable development with closed material loops, the Circular Economy (CE) emerged within the debates. The concept gained increasing attention on national - e.g. in the Netherlands (Dutch Ministry of Environment, 2016) as well as regional (European Commission, 2018) policy targets and is covered increasingly in business sector reports (e.g. Ellen Macarthur Foundation, 2013a, 2013b). The number of academic studies on the CE is increasing, and different authors have reviewed its various definitions and approaches.

While there is no comprehensive definition of the CE concept yet, the main objective of CE is to maintain the value of materials by keeping them in circulation and, consequently, reduce our reliance on material extraction (Kirchherr et al., 2017). According to Hislop & Hill, "the circular economy represents a development strategy that maximizes resource efficiency and minimizes waste production, within the context of sustainable economic and social development" (Hislop & Hill, 2011, p. 2).

However, after decades of discussion and research around CE, the linear model is still deeply entrenched. There are political, economic, technological, and legal obstacles to the transition to a circular economy (Hart et al., 2019). There is a strong need for political support to promote the circular economy concept (Araujo Galvão et al., 2018). The absence of incentives to adopt CE still exists, and new incentives are required to increase the speed of transition to CE.

Approaches to overcome these deficits have their sources in political incentive systems and new production paradigms labelled smart supply chain management in the context of Industry 4.0 (Prause, 2014, 2015; Ahmadov et al., 2022). The main aims of those approaches are laid on the fusion of the virtual and the physical world based on smart internet technologies and networked production processes coming along with energy and resource efficiency, increased productivity, shortening of innovation and time-to-market cycles together with a horizontal and vertical integration through value networks and an end-to-end digital integration of engineering across the entire value chain. Thus, the internet–linked production facilities and networked manufacturing systems open up a machine-to-machine-communication and interaction, called M2M, which allows to name, identify and trace single products during their whole creation process and later on during their lifetime, which generates new perspectives for the entire supply chain including product design and development, operations management and logistics.

Of particular interest for the circular economy is the possibility to identify and trace products during their lifecycle (Eshghie et al., 2022), which opens the opportunity to attach special conditions, services and rights to events during different phases of their lifetime. Recent research stresses the potential of blockchain technologies together with smart contracts to facilitate event-triggered and automatized transactions within supply chains (Philipp et al., 2019). Such blockchain and smart contract platforms allow supply chain parties to encode business rules based on negotiated legal agreements, i.e., a smart contract can be considered as an electronic transaction protocol to enforce digitally the negotiation and execution of the terms of an underlying legal contract designed to fulfil conditions like payments, legal obligations, and enforcement without third parties.

In the circular economy context, such a smart contract realizes the digital execution of legal agreements and linked transactions related to special events on the product lifecycle. Non-Fungible Token (NFT) represent digital assets that can be integrated into blockchains and can be used to realize links to specific data sets and to identify and attribute special features to a product. Besides this, NFT can be used to parametrize smart contracts to realize special services related to the product or to implement and specify smart business models.

The paper highlights the potential of using blockchain technologies together with smart contracts to facilitate event-triggered and automated transactions within supply chains, allowing supply chain parties to encode business rules based on negotiated legal agreements. In the circular economy context, smart contracts can realize the digital execution of legal agreements and linked transactions linked to special events in the product lifecycle. NFTs represent digital assets that can be integrated into blockchains and used to connect specific data sets and identify and attribute special features to a product. NFTs can also be used to parametrize smart contracts to realize special services related to the product or to implement and specify smart business models.

The research presented in this paper is based on literature expert interviews, surveys conducted within the context of European Union (EU) projects focusing on the Baltic Sea Region, and a case study. The author aimed to explore how and to what extent smart contracting, in cooperation with blockchain technology and NFT solutions, can facilitate the implementation of smart business models in the circular economy context.

## 2. Circular Economy

The Circular Economy (CE) concept addresses resource depletion and environmental degradation caused by the linear economic model. The concept of the CE can be traced back to the early 1970s when the Club of Rome, a global think tank, published a report titled "The Limits to Growth" (Meadows et al., 1972). The report highlighted the issue of resource depletion and predicted that the world's resources would be exhausted within the next century if the linear economic model continued to be used. The report called for a new economic model focusing on sustainability and resource efficiency. In the 1980s and 1990s; the idea of CE gained momentum, with several researchers and organizations advocating for a new economic model that focused on waste reduction and resource efficiency. In 1994, Walter R. Stahel, a Swiss architect and economist, coined the term "cradle to cradle" to describe the idea of a closed-loop system that allows for the continuous reuse of resources and materials (Stahel, 2010).

In the 2000s, the CE concept gained traction in business, with several companies adopting CE principles in their operations. In 2012, the Ellen MacArthur Foundation, a UK-based charity, was founded to promote the CE concept globally (Ellen MacArthur Foundation, 2012). The foundation's report, "Towards the Circular Economy: Economic and Business Rationale for an Accelerated Transition," provided a comprehensive overview of the concept and its potential benefits.

In 2015, the CE concept gained global recognition when it was included in the United Nations' Sustainable Development Goals (SDGs). Goal 12 of the SDGs calls for sustainable consumption and production patterns, with a specific target to "implement the 10-year framework of programs on sustainable consumption and production, all countries taking action, with developed countries taking the lead" (United Nations, 2015).

Today, the CE concept is widely recognized as a critical strategy for achieving sustainability and reducing resource depletion and waste. The concept has gained widespread adoption in business, with several companies adopting circular economy principles. The CE concept has also obtained significant support from governments and international organizations, with several countries and organizations developing circular economy strategies and policies.

The CE concept has evolved from a relatively new idea in the 1970s to a mainstream concept in the 21st century. The concept has been supported by businesses, governments, and international organizations and is now recognized as a critical strategy for achieving sustainability and reducing resource depletion and waste. CE has become an increasingly popular topic of discussion in recent years due to its potential to address some of the most pressing sustainability challenges facing society. CE aims to reduce waste and promote sustainable consumption and production by maximizing the value of resources through a closed-loop system. CE is also an economic model that aims to reduce waste and promote sustainable consumption and production. It is based on the concept of closed-loop systems, where resources are kept in use for as long as possible through reuse, repair, and recycling (Ellen MacArthur Foundation, 2013a, 2013b). CE is seen as a way to decouple economic growth from resource consumption and environmental degradation by promoting more efficient use of resources and reducing waste.

The principles of CE are based on the idea of designing waste and pollution, keeping products and materials in use, and regenerating natural systems (Ellen MacArthur Foundation, 2019). These principles are reflected in various practices, such as product design for circularity, closed-loop supply chains, and collaborative consumption models. One of the key principles of CE is product design for circularity, which involves designing products to minimize waste and maximize their lifespan. This can include designing products that are easy to repair, upgrade, or recycle (Bocken et al., 2016). Another essential principle is closed-loop supply chains, which

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involve creating a closed system where materials and products are kept in use for as long as possible (Tukker et al., 2015). This can involve practices such as remanufacturing, refurbishing, and recycling.

There are many examples of CE in practice across various industries and sectors. One example is the textile industry, where circular models are being developed to reduce waste and increase resource efficiency (Ghisellini et al., 2016). This can involve using recycled fibres, designing products for disassembly, and implementing closed-loop supply chains. Another example of CE in practice is the sharing economy, which involves collaborative consumption models promoting the sharing of resources and products (Bardhi & Eckhardt, 2012). This can include practices such as ride-sharing, co-working spaces, and tool libraries.

CE offers a promising approach to promoting sustainable consumption and production by maximizing the value of resources through a closed-loop system. Its principles are reflected in various practices, such as product design for circularity, closed-loop supply chains, and collaborative consumption models. There are many examples of CE in practice across multiple industries and sectors, and policymakers, businesses, and consumers increasingly recognize its potential for promoting sustainable development.

CE is closely related to sustainability, as it provides a framework for economic growth that aligns with sustainable development principles. Sustainability is defined as meeting the needs of the present without compromising the ability of future generations to meet their own needs (United Nations, 1987). The circular economy is seen as a critical approach for achieving sustainability as it seeks to reduce the depletion of natural resources, minimize waste, and lower greenhouse gas emissions (Ellen MacArthur Foundation, 2015).

The circular economy model emphasizes the importance of designing products and services with the end in mind. It involves a shift away from the traditional linear take-make-dispose model to one where resources are kept in use for as long as possible through strategies such as recycling, reuse, and remanufacturing (Kirchherr et al., 2017). By keeping materials in circulation, the circular economy reduces the need for virgin resource extraction, which can have negative environmental and social impacts. The circular economy offers numerous benefits for achieving sustainability. One key benefit is the reduction in resource depletion. By keeping resources in circulation, the circular economy minimizes the need for virgin resource extraction, which can lead to habitat destruction, air and water pollution, and other negative environmental impacts (Kirchherr et al., 2017). Another benefit of the CE is the waste reduction. The circular economy minimizes waste generation by designing products and services for longevity and end-of-life considerations. It encourages the use of resources more efficiently and effectively. This can also reduce the need for landfill space and associated costs (Stahel, 2016). The CE can also create new economic opportunities. For example, the recycling and remanufacturing industries can provide new jobs and revenue streams while reducing the reliance on the traditional linear economic model (Ellen MacArthur Foundation, 2015).

CE promotes the efficient use of resources, reduces the environmental impact of economic activities, and helps to preserve natural ecosystems. These benefits make CE an essential concept for achieving sustainable development and addressing modern challenges while promoting innovation and economic growth.

## 3. Smart Contracts for Smart Supply Chains

Supply chain management (SCM) coordinates and optimizes cross-company business processes based on downstream flows of goods and services and upstream flows of information and finance (Jacobs & Chase, 2020). Coordinating supply chain flows represents a challenging task, and recent research results advocate a significant potential in blockchain technologies for facilitating supply chain management (Gligor et al., 2021).

This enthusiasm towards blockchains stems from the underlying technological concept that uses time-stamped ledgers of transactions without a central authority. In other words, transactions are not recorded centrally, and each party maintains a local copy of the ledger consisting of a linked list of encrypted blocks comprising a set of transactions that are hashed and grouped in blocks and thus broadcasted and recorded by each participant in the blockchain network (Sternberg et al., 2021). When a new block is proposed, the participants in the network agree upon a single valid copy of this block according to a consensus mechanism. Once a block is collectively

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accepted, it is practically impossible to change it or remove it i.e. a blockchain can be considered a replicated append-only transactional data store, which can replace a centralized register of transactions maintained by a trusted authority (Philipp et al., 2019). With blockchain technology, the necessary visibility and transparency can be generated in SCM – which is especially beneficial for SCRM.

A closer look at the term blockchain indicates that often two meanings are mixed, namely a distributed database and a data structure consisting of a linked list of blocks of transactions, where each block is cryptographically chained to the previous one by including their hash value and a cryptographic signature, in such a way that it is impossible to alter an earlier block without re-creating the entire chain since that block. Blockchain platforms additionally offer the possibility of executing scripts on top of a blockchain, called smart contracts, allowing parties to encode business rules like negotiated legal agreements. Thus, a smart contract can be considered an electronic transaction protocol to digitally enforce the negotiation and execution of the terms of an underlying legal contract designed to fulfil conditions like payments, legal obligations, and enforcement without third parties. Such a smart contract realizes the digital execution of legal agreements and linked transactions between distributed units within a network or supply chain with reduced transaction costs, being trackable and irreversible (Prause, 2019).

One of the newest developments in the context of smart contracts is non-fungible token (NFT) representing digital data stored in a blockchain. Such an NFT can be distributed to a specific and exclusive individual owner, i.e. it represents a proof of ownership of a blockchain record and can transferred, i.e. traded. The essential characteristics of NFTs are that they contain links to digital files, are uniquely identifiable, and are easy to create. In particular business sectors, especially in the cultural and creative industry (CCI), NFTs enjoy high economic importance because the linked digital files represent the market value of an NFT. It must be pointed out that NFTs represent a public certificate of authenticity or proof of ownership defined by the blockchain. Still, they do not grant a copyright in the represented object itself – which also means that the author (or licensed user) may create a generally unlimited number of further NFTs representing the same object. Neither do NFTs grant any other legal rights over their associated digital file (Wang et al., 2021) - they are, in other words, a mere "digital label" (e.g., with the function of a price tag) to any object selected to be represented by it.

In a CE context, NFTs can be used as uniquely identifiable tokens that refer to a digital file that stores rights and conditions for certain tripper points in the product lifecycle. Underlying smart contracts can use these NFTs for executing scripts with parameters stored in the digital files, i.e., in such a way, smart contracts can be parametrized through NFTs with actual parameters along the lifecycle of a product.

Overall, there are many benefits associated with blockchain implementation in supply chain management. The study of Ayan et al. (2022) confirms that blockchain technology can enhance supply chain transparency, traceability, and accountability, leading to increased efficiency, reduced waste, and improved environmental and social sustainability. The authors also provide case studies from the food, fashion, and energy industries to illustrate the potential of blockchain in promoting sustainability. Dounas et al. (2021) also state that using NFTs in construction and architecture allows the expansion of Digital Twins applications using blockchain technologies, where components are connected with particular aspects of the building performance and their maintenance is potentially automated through smart contracts. (Dounas et al., 2021).

## 4. Previous research on NFT-enriched Smart Contracts for Circular Economy models

In recent years, a growing share of literature has addressed the applications of blockchain technologies and smart contracts in various sectors. These studies have highlighted the potential of these technologies for improving operational efficiency, transparency, and trust among supply chain participants (Kshetri, 2018; Tapscott & Tapscott, 2016). There is also an emerging body of literature exploring the potential of NFTs, which represent unique digital assets that can be integrated into blockchain platforms (Non-Fungible Tokens, 2021). These studies have suggested that NFTs can provide new ways of managing and verifying ownership, tracking product life cycles, and creating digital twins of physical assets (Adhami et al., 2018; Khaqqi et al., 2018). Consequently, NFT-enriched smart contracts have also gained significant attention in recent years for their

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potential use in circular economy models to safeguard a maximal use of products to save resources or to enhance the possibilities of reuse and recycling.

Navarro et al. (2022) investigated the design, implementation, evaluation, and operation of a verifiable registry for digital product passports of ICT products using blockchain technology. Their experimental results confirm that digital product passports can serve as viable instruments for promoting transparency and environmental accountability in the ICT sector and as an example for other product sectors to meet the world's climate change goals, which are too important to overlook.

Another research by Alves et al. (2022) examined current approaches to traceability in the textile and clothing value chain and explored the technologies necessary for promoting a circular economy in this industry. The specific focus was put on blockchain technology for registering activities on traceable items throughout the value chain and the Internet of Things (IoT) technology for identifying the digital twins of these traceable items. The authors concluded that more efficient and sustainable management of the textile and clothing value chain can be achieved by leveraging these technologies.

A study by Dos Santos et al. (2021) proposes a method for efficient and unrestricted publicity of third-party certification of plant agricultural products using smart contracts and blockchain tokens, providing economic incentives to actors in the supply chain. The study finds that this method can improve food safety and reduce counterfeiting and greenwashing. Implementing tokenization can enhance transparency, promote sustainable consumer behavior, and lead to a more trustworthy supply chain.

Research by Wu et al. (2023) aimed to find a better way to keep track of construction waste material when it's traded across borders. The researchers proposed a blockchain-based solution to create a digital passport for each piece of waste material. The framework involves digitizing into NFT-enabled passports, preventing duplicate issuances, enhancing transparency, improving trading efficiency, and securing transaction records. A prototype of the framework was developed and found to be feasible with satisfactory performance, serving as a reference for future blockchain NFT-enabled passport applications in the circular economy.

## 5. Service Design for Circular Economy

Service Design (SD) is a process that involves creating user-centered services that meet the needs and expectations of users while also considering the broader context in which the service operates. This approach places the user at the center of the design process and emphasizes the importance of understanding user needs, behaviors, and preferences. SD has been used in various fields, including healthcare, education, and retail, to create services that meet users' needs while also achieving business goals. The concept of SD emerged in the early 1990s as a response to the increasing complexity of service provision in the post-industrial economy. Since then, the field has rapidly developed, with practitioners and academics exploring and refining the principles and methods of SD.

SD can be employed to create sustainable business models by addressing the social and environmental aspects of the business. The social aspect of sustainability involves creating services that meet the needs of all stakeholders, including customers, employees, and the wider community. The environmental aspect of sustainability involves reducing the environmental impact of the business by adopting sustainable practices. According to Bitner et al. (2008), SD can help to create sustainable business models by focusing on three key areas: service delivery, service environment, and service communication. Service delivery involves designing services that meet the needs and expectations of customers while also being efficient and effective. Service environment involves creating a physical and virtual environment that supports the service and enhances the customer experience. Service communication involves creating clear and effective communication channels that enable customers to access the service and provide feedback.

A sustainable business model is a business model that generates economic, social, and environmental value. According to Stubbs and Cocklin (2008), sustainable business models involve four key components: economic viability, social responsibility, environmental responsibility, and innovation. Economic viability involves

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creating a profitable business model that generates value for stakeholders. Social responsibility involves creating a business model that considers the social impact of the business on all stakeholders. Environmental responsibility involves creating a business model that minimizes the environmental impact of the business. Innovation involves creating a business model adaptable and responsive to changing market conditions. SD can facilitate the development of sustainable business models by incorporating the four components of sustainable business models into the design process. According to Sangiorgi (2011), SD can facilitate the creation of sustainable business models by adopting a systemic approach that considers the interdependencies between economic, social, and environmental factors. SD can also facilitate the adoption of sustainable practices by involving stakeholders in the design process and creating services that meet the needs and expectations of all stakeholders.

SD can also be beneficial for the creation of smart services discussed in this paper and have the potential to revolutionize the way supply chains operate. Designing and implementing such systems is complex and requires a user-centered approach. Designing services that use Smart contracts technology also requires a deep understanding of the technology and the specific industry in which the service will be applied.

SD employs a range of tools to create and improve the product or service. Two common tools used in SD, such as co-creation, are journey mapping and service blueprint, which can be largely applied to contribute to CE. Journey mapping is a visual tool that maps out a customer's steps when interacting with a service, from initial awareness to post-service follow-up. This tool helps designers and stakeholders identify pain points and opportunities for improvement throughout the customer journey (Stickdorn et al., 2018). Service blueprinting is another tool that visually maps out the service process but from the internal perspective of the service provider. This tool helps identify the different people, processes, and technologies involved in delivering the service and areas for improvement (Bitner et al., 2008). Both journey mapping and service blueprinting are effective co-creation tools for SD, as they involve collaboration between designers, stakeholders, and customers to ensure that services are designed with the customer experience in mind. By using these tools, service designers can create more effective and efficient services that meet the needs of all parties' needs.

SD can create services that utilize Smart Contracts in several ways. One way is by identifying the key stakeholders and their needs and designing the service to meet them using smart contracts. This can include designing the user interface for interacting with the smart contract, as well as the process for creating and executing the contract. Another way SD can be used is by identifying potential pain points or inefficiencies in existing processes and using smart contracts to streamline and automate those processes. This can include using smart contracts to automate payment and settlement processes and enforce compliance with regulatory requirements. SD can also be used to design the governance and decision-making processes for smart contract-based services. This includes designing the process for amending or updating the smart contract and determining the appropriate level of decentralization for the service. As such, organizations need to consider the integration of SD in the development of smart contract-based services. In conclusion, SD can be a valuable tool in creating smart services and dealing with emerging challenges related to CE.

## 6. Methodology

This paper employs a mixed-methods research design that includes expert interviews, desktop research, a literature review, and a case study approach. Using multiple methods allows for a comprehensive and multi-dimensional analysis of the research topic, providing a more robust understanding of the phenomenon under investigation. The expert interviews provide insights from professionals with extensive experience and knowledge in the field. At the same time, the desktop research and literature review offer a broad and systematic review of existing literature and data sources. The case study approach enables in-depth analysis of a particular phenomenon or context, providing a detailed and contextualized understanding of the research topic. Together, these methods provide a rigorous and comprehensive approach to research and analysis.

This paper aims to investigate how smart contracting, in cooperation with blockchain technology and NFT solutions, can facilitate the implementation of smart business models in the circular economy context.

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The research is based on expert interviews, surveys, and a case study conducted in the context of EU projects focusing on the Baltic Sea Region.

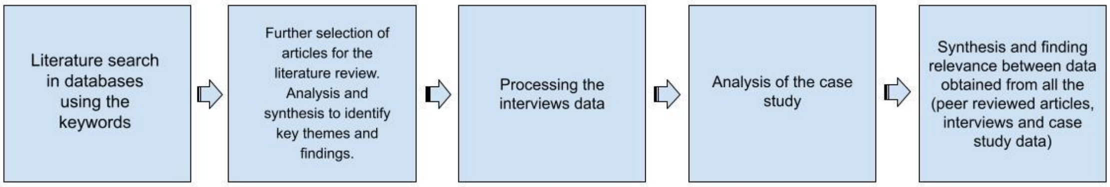


**Figure 1.** Methodological procedure of the study

*Source:* authors' own elaboration

This literature review was conducted using desktop research, which involved a comprehensive search of relevant academic articles and literature from reputable sources. The search used Scopus, Google Scholar, and Web of Science databases. Keywords used in the search included "NFTs," "smart contracts," "circular economy," "blockchain," "supply chain," and "sustainability." The inclusion criteria for articles in this literature review were relevance to the topic, recency, and peer-reviewed status. Articles published between 1999 and 2022 were included to ensure that the most recent and up-to-date research was included. The search initially yielded many results, which were then screened based on their abstract and title to identify relevant articles. After screening the initial results, 20 academic articles were selected for the literature review, representing the most relevant scientific papers related to our study. These articles were then analyzed and synthesized to identify key themes and findings related to the benefits of using NFT-enriched smart contracts in circular economy models.

Overall, desktop research provides a comprehensive and efficient method for conducting literature reviews. It allows researchers to access a vast array of relevant literature from different sources and enables the efficient screening and selection of articles that meet the inclusion criteria. Furthermore, using various databases ensures the inclusion of diverse perspectives and insights, enhancing the validity and reliability of the review's findings. In addition, expert interviews were conducted to understand the potential of smart contracts and NFT solutions in implementing circular economy practices. The interviews were conducted with professionals from various fields, including blockchain technology experts, supply chain managers, and circular economy practitioners. The interviews were conducted using a semi-structured approach, and the questions focused on exploring the role of smart contracts and NFT solutions in circular economy practices.

Surveys were conducted to gather quantitative data on using smart contracts and NFT solutions in circular economy practices. The survey questions were designed to understand the level of awareness, adoption, and perceived benefits of using smart contracts and NFT solutions in circular economy practices. The surveys were distributed among professionals from various fields, including blockchain technology experts, supply chain managers, and circular economy practitioners.

The expert interviews, surveys, and case study data were analyzed using a qualitative and quantitative approach. We review a case study focusing on Alfa Romeo's Tonale hybrid SUV to explore the potential of smart contracts and NFTs in facilitating smart circular economy business models. The qualitative analysis was conducted to identify themes and patterns in the data, while the quantitative analysis was conducted to obtain numerical data on the use of smart contracts and NFT solutions in circular economy practices. The findings from the analysis were used to answer the research question and provide insights into the potential of smart contracting in the context of the circular economy.

The authors aimed to explore how and to what extent smart contracting, in cooperation with blockchain technology and NFT solutions, can facilitate the implementation of smart business models in the context of circular economy. Expert interviews allowed the author to gather insights and opinions from individuals who possess in-depth knowledge and experience in the fields of circular economy, smart contracting, and blockchain

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technology. These experts were selected based on their expertise and experience in the industry, and their opinions were used to shape the research questions and the study. The research comprises 12 interviews that were conducted between September 2022 and March 2023 in Estonia and Germany in a structured format in the frame of national and EU projects on circular economy, allowing the author to gather specific information about the challenges and opportunities associated with implementing smart business models in the context of circular economy.

The survey component of the research aimed to gather data from a larger sample of individuals with varying levels of expertise and experience in the field. The survey was designed to collect information on the use of smart contracts and NFT solutions in the context of a circular economy and identify any barriers to implementation and potential areas for improvement. Finally, a case study was conducted to provide real-world example of implementing smart business models in the circular economy context. This case study was selected based on its relevance to the research questions. It provides insights into the industry's practical applications of smart contracting and NFT solutions.

Overall, the combination of expert interviews, surveys, and the case study provided a comprehensive picture of the challenges and opportunities associated with implementing smart business models in the circular economy context. The gained empirical measures represent a classical multi-method approach combining quantitative and qualitative data from different sources that were analyzed and interpreted using a methodological triangulation approach in the sense of Altrichter et al. (2008) to acquire a more detailed and better-balanced picture of the research situation. Finally, the empirical results of the research are discussed in the context of the current literature.

## 7. Two Case Studies: The Alfa Romeo's Tonale and the EV-Purchasing Model

Alfa Romeo's Tonale hybrid SUV represents a groundbreaking application of blockchain technology and NFTs in the automotive industry. This case study provides insight into how smart contracts and NFTs can revolutionize the automotive industry, transforming customer experiences and influencing business models in the circular economy context.

The Alfa Romeo's Tonale, set to launch in 2023, stands out in the automotive market by incorporating blockchain technology. Each Tonale comes with a complimentary NFT a digital certificate linked to the vehicle (Alfa Romeo, 2023). This digital certificate will continuously update with essential vehicle data, ensuring a consistent and reliable record of the vehicle's history. Hence, the NFT records and updates information about maintenance and milestones, such as reaching 100,000 miles. It provides a well-documented vehicle history, offering added value to the owner if the vehicle is ever sold. This utilization of NFTs offers an innovative solution to a longstanding issue in the used car market – information asymmetry and difficulty verifying a vehicle's history.

Moreover, smart contracts' realized integration with NFTs could automate various vehicle-related transactions. For instance, smart contracts could be set to trigger maintenance services when the vehicle reaches certain milestones. This innovative approach illustrates how blockchain technology, when integrated with smart contracts and NFTs, can significantly enhance automotive companies' customer experience and service efficiency. Thus, integrating smart contracts, NFTs, and service design in Tonale's model can potentially revolutionize the automotive industry's business model. For instance, a "product-as-a-service" model could be explored, wherein customers pay for access to the vehicle rather than its ownership. Such a model could encourage manufacturers to design more durable, repairable, and recyclable vehicles since they would be responsible for their end-of-life management.

The Tonale case demonstrates that a well-implemented service design can ensure a consistent supply of used materials to recycling plants. The digital certificate, in this case, adds value to owners who keep their vehicles well-maintained and reach certain usage milestones, motivating them to contribute to circular economy aims, i.e. this system also facilitates the resale process, as the digital certificate provides potential buyers with an entire, reliable history of the vehicle. The service design process requires collaboration among various

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stakeholders, including manufacturers, dealers, service providers, and customers. This can ensure a seamless transition of the product through its lifecycle and enhance the transparency of the product lifecycle, particularly for complex products such as cars. In conclusion, the Alfa Romeo Tonale case demonstrates how the innovative combination of blockchain technology, smart contracts, NFTs, and service design can substantially enable the automotive industry to contribute to the circular economy. This case study provides valuable insights that could guide future research and policy-making initiatives to promote adopting these technologies in various industries.

A second case highlights the role NFT's can play in business model development. In recent times, new business models have emerged that leverage the use of electric vehicles (EVs) to enhance sustainability. The discussed case represents an anonymized company, well-known to the authors and based in Estonia. It purchases brand-new electric cars directly from manufacturers at discounted prices, rents them to individuals, and replaces them when they reach 10,000 km. It presents an interesting case for examination. While this model may seem unsustainable at first glance due to the rapid turnover of vehicles, some aspects could be considered eco-friendly. The cars are electric, reducing carbon emissions during usage (Hawkins et al., 2013). Moreover, the low mileage at which the cars are sold in the regular market suggests that the vehicles will still have a long life ahead of them, potentially replacing older, less efficient vehicles.

A closer view to the benefits of the EV Turnover Model reveals the implicit sustainability aspects to this model:

1. Lowered Carbon Footprint: By maintaining a fleet of new electric vehicles and ensuring their rapid turnover, these companies ensure that the cars on the road are equipped with the latest energy-efficient technologies. Such practices can lead to reduced greenhouse gas emissions over the vehicle's operational life (Sprei & Ginnebaugh, 2018).
2. Second-Life Utility: Selling a car after just 10,000 km ensures that it remains in near-pristine condition, which could substitute and effectively retire an older, potentially more polluting vehicle on the road. This means these vehicles will likely serve two owners throughout their lifespan, optimizing their utility (International Energy Agency, 2019).
3. Economic Incentives for Sustainability: The model also offers a unique economic proposition by allowing consumers to regularly experience new vehicles without long-term commitment, thereby potentially increasing the adoption rate of EVs (Sierzchula et al., 2014).
4. Promotion of Electric Vehicles: By making the latest electric vehicles accessible and affordable to the general public through leasing, this model indirectly promotes the transition from conventional fuel-based vehicles to electric ones. This transition is crucial for reducing the overall carbon footprint of the transportation sector (International Energy Agency, 2019).

By comparing the EV model with the Alfa Romeo Tonale hybrid SUV, it becomes evident that the latter offers more comprehensive sustainability features. For example, Tonale's NFT system keeps a digital record of the vehicle's history, promoting responsible ownership and potentially extending the vehicle's lifespan (Alfa Romeo, 2023). This contrasts with the business model described above, which focuses on quick turnover rather than long-term utilization and accumulating a well-documented history (McKinsey & Company, 2017).

## 8. Results and Discussion

Both models aim to capitalize on the transition to cleaner and more sustainable forms of transportation; Tonale's approach offers broader implications for a circular economy. By incorporating blockchain technology and NFTs, Alfa Romeo supports sustainability and enhances customer experience and operational efficiency (Geissdoerfer et al., 2017). In juxtaposition, the Alfa Romeo Tonale hybrid SUV offers a different layer of sustainability and innovation. Beyond its hybrid functionality, its integration of NFTs to provide a digital log of the vehicle's history promotes extended vehicle life cycles and responsible ownership, leading to new features in the classical business models in the car sector (Alfa Romeo, 2023):

1. Digital Accountability: The NFT system, by offering an indisputable, continuous record of the car's milestones and maintenance, fosters an environment of accountability. This might discourage rapid turnover and encourage longer ownership, which has sustainability implications (Ajanovic & Haas, 2016).

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2. Market Valuation: Such well-documented histories can elevate the vehicle's second-hand market value. Prospective buyers would be more inclined to purchase a vehicle with a transparent record, ensuring these vehicles remain in circulation for longer (Delucchi & Lipman, 2001).
3. Circular Economy Aspects: Tonale's approach, encompassing the fusion of technology like blockchain and NFTs, underscores the broader goals of a circular economy. Through lifecycle traceability and fostering responsible ownership, the potential waste and rapid turnover could be curtailed (Geissdoerfer et al., 2017).

Conclusively, while both models advocate for eco-friendliness and sustainability, they do so from different angles. The EV turnover model emphasizes rapid renewal, whereas the Tonale hybrid SUV leans towards comprehensive lifecycle management.

Navigating the sustainable landscape presented by Alfa Romeo's Tonale hybrid SUV and contrasting it with alternative EV business models, one can appreciate the multifaceted approaches toward achieving sustainability in the automotive domain (Geissdoerfer et al., 2017). Both models signify the industry's shift towards greener practices; however, their differences illuminate the vast spectrum of sustainable opportunities and challenges. As smart contracts and NFTs steadily permeate this industry and business models evolve to prioritize sustainability, the journey towards a cleaner, more efficient automotive future gains momentum (Tapscott & Tapscott, 2016; Kshetri, 2017). This discourse serves as a testament to the industry's commitment to sustainability and the innovations that arise from it.

Summing up the review of the two distinct cases - the Alfa Romeo's Tonale Hybrid SUV's integration of NFT technology and the sustainable business model of purchasing, renting, and reselling electric cars - several recommendations emerge for stakeholders in the automotive industry:

1. Digital Integration and Traceability: The integration of NFTs by Alfa Romeo showcases the potential of digital traceability in enhancing the car ownership experience. Manufacturers should explore the possibility of integrating similar technologies, not just as a value proposition for consumers but also as a measure to ensure proper maintenance longevity and even to reduce fraudulent practices in used-car markets (Tapscott & Tapscott, 2016).
2. Sustainable Business Models: Purchasing electric vehicles, renting them out until a set mileage, and then selling them is an innovative approach that speaks to a broader strategy. It reduces the environmental impact by promoting electric vehicle usage and ensures cars have a longer life cycle with multiple users. Other companies can adopt similar models, emphasizing economic benefits and environmental sustainability (Eisenhardt & Graebner, 2007).
3. Incentives for Electric Vehicles (EVs): Given the environmental advantages of EVs, governments and policymakers should provide further incentives to consumers and businesses that promote their usage. This could include tax breaks, grants for R&D in sustainable transport, or even subsidies for consumers.
4. Collaborative Initiatives: As seen in the two cases, innovation often results from a synergy of different sectors - tech and automotive, in the case of Alfa Romeo, and the rental and resale market in the electric car business model. Collaborative efforts between industries can lead to groundbreaking business models and sustainable solutions (Chesbrough, 2003).
5. Consumer Education: The success of both models largely depends on consumer acceptance. It's essential to invest in consumer education initiatives about the benefits of such models, both in terms of personal benefits (like the NFT's ability to record car data) and broader societal advantages (such as the environmental benefits of EVs).
6. Adaptable Supply Chains: In an era of rapid technological advancements, automotive companies should ensure adaptable supply chains. This adaptability allows for the quick integration of innovations, whether they are in the realm of digital tech like NFTs or in sustainable business practices.
7. Research and Development: Continued investment in R&D is essential. Both cases underscore the significance of innovation in driving the industry forward. Auto companies should allocate resources to refine existing models and pioneer new, disruptive solutions that cater to an evolving market and a planet needing sustainable solutions.

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Consequently, while the two cases present unique strategies and outcomes, they collectively highlight the automotive industry's vast potential for innovation, sustainability, and consumer-centric solutions. Adopting these recommendations can benefit individual stakeholders and pave the way for a more sustainable and efficient automotive ecosystem. Hence, the potential of using smart contracts together with NFTs to facilitate the implementation of smart circular economy business models, using the case of Alfa Romeo's Tonale hybrid SUV as a reference. The research is based on expert interviews, surveys, and a case study conducted in the context of EU projects focusing on the Baltic Sea Region.

The authors emphasize the need for an alternative model of sustainable development with closed material loops in terms of the CE, which maintains the value of materials and reduces reliance on material extraction. The linear model is still deeply entrenched due to political, economic, technological, and legal obstacles, and the transition to a circular economy requires political support and incentives. Hence, smart supply chain management and Industry 4.0 approaches aim to fuse the virtual and physical worlds based on smart internet technologies and networked production processes. These approaches open up machine-to-machine communication and interaction, allowing for the identification and tracking of products during their lifecycle, which generates new perspectives for the entire supply chain, including product design and development, operations management, and logistics.

The results of this study suggest that smart contracting, blockchain technology, and NFT solutions can facilitate the implementation of smart business models in the context of the circular economy. The study found that smart contracts enable automated, secure, and transparent execution of agreements and transactions, which can reduce the transaction costs associated with traditional contracts. Smart contracts can also ensure that the terms of agreements are executed as intended, without the need for intermediaries.

The study also found that NFTs can be used to create digital representations of physical assets, which can be used to verify their authenticity and ownership. NFTs can also be used to encode special features and conditions related to the product, such as its environmental impact, recycling potential, and end-of-life options. This allows for the creating of smart business models that incentivize sustainable practices and promote circular economy principles. Furthermore, the study found that the combination of smart contracts and NFTs can enable the creation of new business models, such as "product-as-a-service", where customers pay for access to the product rather than ownership. This can encourage manufacturers to design more durable, repairable, and recyclable products, as they would be responsible for the end-of-life management of the product.

The study also highlights that SD can be crucial in ensuring a consistent supply of used materials to recycling plants. By using SD principles, a system can be created that encourages suppliers to provide a steady flow of used products that meet the quality and quantity requirements of the recycling plants. One approach to achieving this is designing a supply chain that considers the needs and motivations of all stakeholders involved. Prause (2015) states that a sustainable business model should motivate the product owner to contribute to circular economy aims, which can be achieved through different incentive types, including refund systems and tax incentives.

The case of the Tonale hybrid SUV by Alfa Romeo comes with a complimentary NFT, essentially a digital certificate, which continuously updates with information about the vehicle, tracking maintenance and milestones (Alfa Romeo, 2023). This innovative approach embodies the seamless blend of physical and digital realities, creating a robust ecosystem of information around the product and thereby enriching its value and lifecycle management.

This case study demonstrates the potential for smart supply chain management and Industry 4.0 approaches, allowing for identifying and tracking products during their lifecycle, thereby opening up new perspectives for the entire supply chain, including product design and development, operations management, and logistics. Thus, smart contracts, coupled with blockchain technologies, allow for event-triggered and automated transactions within supply chains. This revolutionary method enables supply chain parties to encode business rules based on

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negotiated legal agreements. In the context of a circular economy, smart contracts realize the digital execution of legal agreements and linked transactions corresponding to special events in the product lifecycle.

Tonale's NFTs represent digital assets integrated into blockchains, used to link specific data sets and identify and attribute special features to the product. NFTs can be used to parameterize smart contracts to realize special services related to the product or to implement and specify smart business models. Hence, the Alfa Romeo Tonale case study shows that the combination of smart contracts and NFTs can enable the creation of new business models, such as product-as-a-service, where customers pay for access to the product rather than ownership. This encourages manufacturers to design more durable, repairable, and recyclable products, as they would be responsible for the end-of-life management of the product.

The Tonale case also shows how service design can be crucial in enhancing the overall user experience. By tracking and documenting the vehicle's history, users can have a clear picture of the vehicle's status, facilitating maintenance and improving resale value. A system can be created that encourages owners to maintain their vehicles well and reach usage milestones, motivating more sustainable behavior.

To design an effective incentive system, service design techniques such as journey mapping and co-creation can be utilized. By considering the needs and motivations of all stakeholders involved, a sustainable business model can be established that motivates vehicle owners to contribute to circular economy aims. In conclusion, the Tonale case provides an effective model for incorporating blockchain technologies, smart contracts, and NFTs into the automotive industry, presenting new business models and approaches to contribute towards a circular economy. It demonstrates how NFTs can bridge the physical and digital worlds, facilitating new ways of managing and interacting with products.

Finally, the study identifies challenges associated with adopting smart contracts and NFTs in the circular economy context, such as the need for standardization of smart contract templates, the development of interoperable NFT standards, and the legal recognition of smart contracts and digital assets. Furthermore, it suggests the need for education and awareness-raising among stakeholders regarding these technologies' potential benefits and challenges.

## 9. Conclusions

Smart contracts, blockchain technologies, and NFTs are reshaping the contours of supply chain management and the broader scope of the circular economy. These technologies offer potential far beyond cost reduction, facilitating cross-organizational business processes, promoting transparency and traceability, and paving the way for innovative business models. This paper explores the utility of these digital tools in the context of circular economy, using the case of Alfa Romeo's Tonale hybrid SUV as a case study. The Tonale case demonstrates how an NFT, essentially a digital certificate, can become an integral part of the product lifecycle, constantly updating with information about the vehicle, including maintenance and milestones. This offers valuable insights for the vehicle owners and potential future buyers, thus contributing to a more efficient and transparent used car market. Hence, it showcases how innovative technological applications can promote product durability, repairability, and recyclability, all cornerstones of the circular economy. It also exhibits how these digital tools can catalyze new business models like product-as-a-service, shifting the focus from product ownership to product utility.

In summary, implementing smart contracts and NFTs facilitates the creation of robust, well-documented product lifecycles, empowering consumers, producers, and suppliers alike. They pave the way for dynamic and adaptable supply chains that cater to the evolving needs of stakeholders, thereby contributing towards a sustainable and circular economy.

Nonetheless, the study also acknowledges the challenges in integrating smart contracts and NFTs into the broader economic landscape, including issues surrounding legal recognition, the need for standardization, and the development of interoperable standards. There is also an evident need for increased education and

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awareness among stakeholders regarding these emerging technologies, their potential benefits, and associated challenges.

Ultimately, this research advocates for the continued exploration and integration of such digital tools in various industries, contributing towards the transition to smart supply chains and circular economies. The findings and discussions from this paper can be utilized to develop future policies and initiatives aimed at promoting smart contracting and NFT solutions across industries.

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