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DIGITALIZATION OF THE SUPPLY CHAIN IN SUPPORT OF THE CIRCULAR ECONOMY

Abstract: The aim of this paper is to investigate the role of digitization of business processes in supply chain management and its contribution to the implementation of circular economy principles. Special focus is placed on the possibility of unifying data from various specialized software solutions to enable more efficient analysis of supply chain performance and making informed decisions that support sustainable development.
The methodology of the work is based on the analysis of existing research and examples from practice, whereby the connection of digital technologies with the improvement of energy efficiency and the use of renewable energy sources is examined. The circular economy, in part, is based on the principle of promoting and expanding opportunities for the use of renewable energy sources with the goal that all systems reach the level of constant use of renewable and sustainable energy sources and on the principle of encouraging human activity and utilization of resources in order to achieve new value. It is precisely in the supply chain management segment in the context of business digitalization that the principle of encouraging human activities to follow technological trends can be reflected. Also, innovative approaches in business that can contribute to the optimization of resources and the reduction of the ecological footprint are being considered.
The conclusion of the paper indicates that digitization is a key tool for the implementation of the circular economy, enabling more efficient management of data and resources in the supply chain. Through the integration of digital solutions, companies can redefine their strategies and harmonize economic, environmental and technological goals, which opens up space for sustainable economic development.

Keywords: Circular economy, digitization, supply chain, sustainable development

1. INTRODUCTION

Understanding the circular economy and its benefits for sustainable societal development requires an analysis of its fundamental principles and objectives. A key principle of the circular economic model is keeping products and materials in use for as long as possible. The advantages of this approach lie in preserving added value through more efficient use of material and energy resources, as well as human labor (Geissdoerfer et al., 2017). Therefore, it is essential that products, their components, and materials remain in circulation through designs that enable durability, reuse, repair, remanufacturing, and recycling (Ellen MacArthur Foundation, 2015).
The second key principle of the circular economy is the elimination of waste and pollution. The implementation of the circular economy aims to reduce the negative effects of production activities on the environment and human health. This model enables the reduction of natural resource consumption, greenhouse gas emissions, and other hazardous

substances generated as byproducts in production processes. It also contributes to reducing air, water, and land pollution by significantly decreasing waste volumes (Bogetić, Stojković & Dokić, 2021).
The third principle of the circular economy is reflected in the regeneration and restoration of natural systems. Implementing this model leads to reduced use of non-renewable resources and better conservation of renewable energy sources and raw materials. The circular economy is a regenerative economic model that positively impacts all forms of capital: natural, social, financial, and human (Ghisellini, Cialani & Ulgiati, 2016). Its goal is to restore degraded ecosystems, extend product lifecycles, and minimize waste through thoughtful design that prevents products from becoming waste after use (Bocken et al., 2016).
Innovation, digitalization, and the application of new technologies can significantly accelerate the transition to a circular and green economy, ensuring not only resource and environmental conservation but also enhancing economic competitiveness (Murray, Skene & Haynes, 2017). The circular economy redefines the concept of production and consumption through a new approach to design, resource utilization, and waste management. In this model, waste does not exist; instead, materials and resources are reused in the same or other production processes (Kirchherr, Reike & Hekkert, 2017).
The transition to a circular economy brings long-term benefits for the economy and businesses through innovation, improved brand image and consumer loyalty, increased productivity, and reduced operational costs (Ellen MacArthur Foundation, 2019). The European Union is currently undergoing two parallel transitions affecting economic and societal transformation: the shift from a linear to a circular economic model and digital transformation (European Commission, 2020). Digitalization enables more efficient information exchange and the application of modern technological solutions, while a successful transition to a circular economy requires continuous communication, strong collaboration among various stakeholders (government, industry, consumers, waste management sector), and the implementation of technical solutions such as product eco-design, recycling, and repair (Lieder & Rashid, 2016).
Recycling, as one of the key processes in the circular economy, involves collecting, sorting, processing, and reusing materials from waste for the same or similar purposes. This economic model can provide Serbia with development opportunities, ecological security, "green" jobs, improved water and air quality, healthy food, and an overall higher quality of life for its citizens (Aćimović & Mijušković, 2021). At the same time, the challenges of digitalization and innovation influence global economic processes, with information technology and electronics redefining traditional globalization drivers and fostering sustainable development (Stahel, 2016).

2. DIGITAL TECHNOLOGIES IN THE SUPPLY CHAIN

In contemporary business environments, constant change and adaptability have become prerequisites for market participants. As a result, existing business philosophies are continuously refined, while new concepts emerge to address the challenges posed by dynamic market conditions. One such philosophy, supply chain management, has garnered significant attention from both academia and industry over the past three decades. During this period, various business concepts and strategies have been developed to enhance and optimize supply chain operations. However, no single approach provides a universally optimal solution for all participants in every scenario. Therefore, understanding the appropriate application of these tools is crucial (Aćimović & Mijušković, 2020).
Over the past two decades, supply chains have increasingly adopted business models capable of meeting the demands of global markets. A common characteristic of these models is the integration of sustainability principles into operations. The circular business model in supply chain management is particularly comprehensive, as it considers environmental, economic, and social objectives equally. Circular supply chain management (CSCM) entails the incorporation of circular economy principles into supply chain operations and industrial and natural ecosystems. By pursuing a zero-waste vision, organizations systematically renew technical materials and regenerate biological resources through innovative business models and supply chain functions, spanning all phases from product design to end-of-life management (Farooque et al., 2019).
CSCM engages all stakeholders throughout a product's lifecycle, including manufacturers, suppliers, consumers, and end-users. The core principle of the circular economy is to maximize resource utilization and value extraction (Nasir et al., 2017). CSCM involves the strategic configuration and coordination of functions such as marketing, sales, research and development, production, logistics, information technology, finance, and customer service. This approach minimizes resource intake, waste leakage, and emissions while enhancing operational efficiency and fostering competitive advantage. Moreover, fostering collaboration among supply chain participants through digital innovations is vital for optimizing circular supply chain operations (Aleksić, Vujović, & Arsić, 2023).
To achieve a balance between economic, environmental, and social goals, businesses must leverage Industry 4.0 technologies, which play a crucial role in redesigning and implementing circular supply chain models. Digital technologies facilitate process acceleration, resource optimization, cost reduction, and profitability enhancement across supply chain operations. The rapid advancement of technological innovation and digitalization has compelled organizations to allocate resources in their development plans for the transformation of specific functions or entire business models. However, economic globalization and global policy decisions may also influence the pace of digital transformation (Aleksić et al., 2023).

Digital transformation integrates information, communication, and computing technologies within the supply chain, establishing a strategic imperative for businesses seeking competitive advantage. Key aspects of digital transformation include automation and the implementation of intelligent communication technologies to optimize procurement, warehouse logistics, and equipment management. Information technology specialists develop tailored IT solutions to enhance logistics efficiency. Digitalization enables comprehensive control and management of logistics processes, from procurement and production logistics to distribution (Aleksić et al., 2023).
A significant component of digital transformation is the digitization of procurement processes, which facilitates database management of potential, current, and past suppliers. This automation enhances the efficiency of e-procurement phases, such as supplier evaluation. Another key element of circular digital transformation is the adoption of smart production systems, which integrate advanced manufacturing techniques, operational technologies, and information and communication technologies. These systems replace traditional hierarchical structures with collaborative networks of specialized production components, thereby improving cost control and performance (Stock et al., 2018).
Automated production and recycling processes contribute to efficiency gains by reducing waste generation and energy consumption. Although digitalization and circular economy principles are inherently compatible, successful integration is not guaranteed. Public policies on the circular economy must consider digitalization to prevent misalignment between these two transformative processes. While circular economy policies may overlook digitalization opportunities, digital transformation initiatives may fail to address potential negative impacts on economic circularity. Therefore, a holistic approach is required to ensure the mutual reinforcement of digitalization and circular supply chain management (Bressanelli et al., 2018).
Table 1 will be presented, outlining the key loops in the circular supply chain, which focus on strategies for reusing materials, extending product lifecycles, and enhancing resource efficiency.

Table 1: Loops in the circular supply chain

Loops in the circular supply chain	
loop closure	It defines the practice of reusing materials through recycling, reuse production and similar processes (Bocken et al., 2016; Geissdoerfer et al.,2018).
slowing down loops	Extended use and reuse of products over time, through processes such as designing durable products and extending product life cycles (Leising et al., 2018).
Loop intensification	It suggests greater utilization of materials and finished products through sharing or consumption (Geissdoerfer et al., 2018).
decreasing loops	Using fewer resources per product (Bocken et al., 2016).
dematerialization of loops	It refers to the exchange of goods for services, in such a way as to increase utility and the lifetime of products and materials (Geissdoerfer et al., 2018)

Source: Adapted from Hazen, B. T, Russo, I, Confente, I, & Pellathy, D. (2021). Supply chain management for circular economy: conceptual framework and research agenda. The International Journal of Logistics Management, 32(2), 510–537.

Table 1 is important because it categorizes key strategies for implementing circular supply chain management. Each loop represents a different approach to resource efficiency, emphasizing reuse, extended product lifespan, and reduced material consumption. Loop closure focuses on recycling and reuse, while slowing down loops promotes durability and longevity. Loop intensification encourages sharing and higher utilization rates, whereas decreasing loops aims to minimize resource use per product. Finally, dematerialization highlights the shift from goods to services to enhance sustainability. Understanding these loops helps businesses optimize their supply chains, reduce waste, and align with circular economy principles.

3. THE BENEFITS OF DIGITIYATION FOR THE CIRCULAR ECONOMY

The integration of digitization into the circular economy plays a pivotal role in enhancing the efficiency, transparency, and sustainability of supply chains. As the world transitions towards more sustainable business practices, the role of digital technologies becomes increasingly crucial in supporting the principles of the circular economy. By leveraging technologies such as big data, the Internet of Things (IoT), artificial intelligence (AI), and blockchain, businesses can optimize their operations, reduce waste, and increase the reuse of resources, all of which are essential components of the circular model.
One of the main benefits of digitization in the circular economy is the ability to track and manage resources throughout their lifecycle. The use of IoT devices, for instance, enables real-time monitoring of products, materials, and waste, providing valuable insights into their condition, location, and potential for reuse. This data-driven approach allows for the identification of inefficiencies and waste points in the supply chain, facilitating corrective actions that align with circular economy objectives (Bocken et al., 2016; Geissdoerfer et al., 2018).

Additionally, blockchain technology enhances transparency and traceability in the circular supply chain. By providing a secure and immutable ledger for transactions, blockchain enables businesses to track the origin and journey of products and materials. This is particularly beneficial for ensuring the authenticity of recycled materials and ensuring that they meet quality standards. Furthermore, blockchain supports the implementation of closed-loop supply chains, where materials are returned to the production process after their use, thus minimizing waste and reducing the need for virgin resources (Hazen et al., 2021).

AI and machine learning also contribute significantly to the circular economy by improving decision-making processes. These technologies can analyze large volumes of data to predict demand, optimize production schedules, and reduce material waste. AI algorithms can suggest more efficient ways to use resources, thereby contributing to more sustainable manufacturing practices. Moreover, AI-driven systems can identify opportunities for product redesign, ensuring that products are built for longevity, repairability, and eventual recycling (Nasir et al., 2017).

The digitalization of logistics processes further accelerates the circular economy by improving the efficiency of transportation and warehousing. Digital platforms enable the real-time tracking of inventory, reducing the need for excess stock and minimizing the carbon footprint associated with transportation. Additionally, by automating logistics and using advanced analytics, businesses can reduce energy consumption, lower emissions, and enhance the overall sustainability of their operations (Aleksić et al., 2023).

In conclusion, the benefits of digitization for the circular economy are manifold, ranging from improved resource management and waste reduction to increased efficiency and enhanced transparency. As digital technologies continue to evolve, their integration into circular supply chains will be essential for driving the transition towards a more sustainable, resource-efficient future. Companies that embrace these digital solutions will not only contribute to environmental protection but will also gain a competitive advantage in the rapidly evolving global marketplace.

4. ANALYSIS OF SUCCESSFUL DIGITALIZATION IMPLEMENTATIONS IN THE CIRCULAR ECONOMY

Circular economy (CE) represents an economic model based on sustainability, resource reuse, and recycling. Digitalization plays a crucial role in its implementation, as it enables more efficient resource management, product life cycle tracking, and waste reduction. According to Zahariev, Manole, and Barbu (2024), digitalization facilitates the flow of information about products and resources, ensuring that all stakeholders are connected throughout the product's life cycle. This is important for reducing the need for new raw materials and ensuring sustainable operations in a circular economy.

Digitalization of the supply chain is one of the most vital aspects of the circular economy. As Zahariev et al. (2024) note, this process allows tracking and managing all stages of a product's life cycle—from production to recycling—thereby reducing resource consumption and promoting sustainability. The use of technologies such as blockchain, the Internet of Things (IoT), data analytics, and automation can significantly improve efficiency and traceability in this process (Van Buren et al., 2016). These technologies enable better monitoring and optimization of resource use, which is essential for creating closed-loop systems.

Examples of successful digitalization implementations in the circular economy can be found in various industries, such as the textile industry, IT sector, and electronics manufacturing. In the textile industry, companies like H&M and Adidas are using digital platforms for the collection and resale of recycled materials (Zahariev et al., 2024). This approach reduces waste and increases the use of recycled materials in production, contributing to a more sustainable business model. In the IT industry, companies such as Apple and Dell use digital technologies for recycling and reusing materials in the production of their devices, promoting a reduction in the demand for new raw materials (Corsten et al., 2013).

Additionally, the application of blockchain technology in resource tracking has become an important tool in the circular economy. Blockchain allows for greater transparency and traceability of product materials, making recycling and resource reuse more efficient. For example, Stevanović (2021) discusses how a blockchain-based platform in Serbia enables the collection and distribution of surplus fruits and vegetables, reducing food waste and improving resource management in the agriculture sector.

Table 2 Examples of Successful Digitalization Implementations in the Circular Economy

Industry	Company/Project	Implemented Technology	Goal/Outcome
Textile Industry	H&M, Adidas	Digital platforms for recycling	Increase in recycled materials and reduction of waste
Electronics Production	Apple, Dell	Automation, material recycling	Reduction of new raw materials and recycling old devices
Electronic Waste Recycling	Tech Industri Bulgaria	Digital collection network for waste	Regeneration of hazardous waste and reduction of environmental impact

Food Tech/Agriculture	Delhaize Serbia, Food Bank Belgrade	Blockchain platform for food distribution	Efficient distribution of surplus fruits and vegetables, waste reduction
Plastic Production	Big Bam Boo	Digitalized production process	Reduction of plastic material use and use of biodegradable alternatives

Source: Authors' own research

The implementation of digitalization in the circular economy not only helps reduce the ecological footprint but also fosters the creation of new business models based on sustainability. According to Van Buren et al. (2016), companies using digital technologies can track products throughout their life cycle, from production to recycling. This approach enables the identification of resource consumption in real-time, which helps reduce waste and encourages responsible consumption.

In addition to reducing waste, digitalization also facilitates the development of new business models that are more sustainable. As Zahariev et al. (2024) highlight, digital tools allow businesses to track and optimize their use of resources, reducing dependence on new raw materials and enabling the reuse of existing resources. These models, based on circular economy principles, foster long-term sustainability and reduce pressure on global resources.

5. CONCLUSION

Based on the results of this research, we can conclude that circular economy in Serbia has developed to a higher level than in earlier period, for example, in the last decade. The transition to a circular economy represents a fundamental shift in modern business practices, addressing both ecological and economic challenges associated with the traditional linear model. By prioritizing resource efficiency, waste minimization, and sustainable innovation, circular strategies contribute to long-term business competitiveness, economic resilience, and environmental preservation.

Despite its numerous advantages, the implementation of circular models faces significant challenges, including high initial costs, regulatory gaps, and consumer behavior inertia. Overcoming these barriers requires coordinated efforts from governments, industries, and consumers, supported by financial incentives, infrastructure development, and educational initiatives.

Ultimately, the circular economy represents a viable path toward a more sustainable and resilient global economy. By embracing circular principles, businesses and policymakers can not only mitigate environmental impact but also unlock new economic opportunities, ensuring long-term sustainability and prosperity.

Digital technologies ensure success for circular supply chains. With their help, the desired goals can be achieved much faster than would be possible without the application of digital technologies. Internet of things, big data, artificial intelligence, machine learning and blockchain technologies ensure adequate integration and increased cooperation between actors in the supply chain. In this way, they enable better monitoring and management of material flows, resources and information through circular supply chains.

Digital technologies support the automation and optimization of processes in circular supply chains, which leads to the achievement of better business results, such as the reduction of production costs, greater efficiency in control and risk reduction, predictive analysis and efficient exchange of information, efficient resolution of complaints, as well as efficient provision of after-sales services. The research determined that Industry 4.0 technologies such as 3D printing and robotics have no significant application in circular supply chains in Serbia.

Thanks to the digitalization of circular supply chains, both in Serbia and in the wider international context, it contributes to the development of theory and practice in the field of circular supply chains. Future directions of research can be aimed at a larger number of companies and industries both from the Republic of Serbia and from the region, in order to achieve representativeness of the results. Considering that the respondents were of the opinion that robotics do not have a significant application in circular supply chains, it is necessary to conduct research in order to determine the possibilities of these digital technologies in circular supply chains.

Digital transformation is a tool that provides companies with a competitive advantage and supply chain efficiency. Digital solutions and innovations must be constant, and companies use market research, forecasts and feedback to make decisions about strategies for implementing new technologies. Investing in technology requires large financial expenditures, and the decisions made about the implementation of technology must be supported by facts that correspond to the description and methods of doing business. It is precisely through the digitalization of supply chains that support for the circular economy can be given, because in this way the task of the supply chain will be realized in terms of a successful response to consumer demands and needs.

Future research will be oriented toward the investigation of the field in society which had a good experience by implementing the digital technology in circular economy. Namely, research and implementation of new technologies must not stagnate - increasing consumer satisfaction results in increased sales and redesign of existing digital solutions. When making strategic decisions about the design of supply chains, technology becomes a requirement without which companies cannot operate today. Acceptance of new laws related to socially responsible business would not be so

effective without digital solutions. That is, new challenges that appear on the market are more easily accepted and solved with digital technology in circular economy.

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