**The study of variables that influence the implementation of a waste cycle tracking system: a literature review**

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**Abstract**

The new economic paradigm of the circular economy aims to recover, sustain and increase the value of waste, corroborating the concept of sustainability, a key point of the new blockchain models outlined by the 2030 Agenda. Our analysis proposes the study of variables that influence the implementation of a waste cycle tracking system. This type of research is relevant to several fields, both academic and professional, as the conceptual understanding of the narratives of traceability drives practical application through the study of strategies, monitoring tools, and technologies among which the Blockchain emerges (Saberi et al., 2018; Steenmans and Taylor, 2018). To date, this technology is an essential tool for the traceability of all economic resources, particularly in the context of the circular economy, which lays the foundation for the development of a model in which the entire life cycle of products is aimed at lasting as long as possible. The use of this technology in the waste sector represents an application of supply chain management on which much attention is being paid in recent years (e.g., Kouhizadeh and Sarkis, 2018; Saberi et al., 2019). The methodological approach used is qualitative as we proceed with a literature review that investigates the variables, in particular blockchain technology, which may influence the application of a traceability model whose purpose is to ensure the certainty and transparency of the individual processes involved. The review also outlines application gaps and future areas of research. The following article could enhance the use of this technology, as well as offer insights into the study of other technological variables always to be applied within a yet unknown waste traceability model.

**Keywords**

blockchain; circular economy; sustainability; waste management; technology; SDGs12.

# Introduction

This contribution starts from some important questions that help us to outline a theoretical framework as well as to define some fundamental concepts: what do we mean by waste? When and how does a waste become a second raw material (SRM*)*, and what are the criticalities of this process? The concept of waste finds its definition in the Italian legislation which in art. 183 of Legislative Decree No. 152 of 3 April 2006 of the Consolidated Environmental Law, states: " *Any substance or object that the holder discards or is obliged to discard ".* The important novelty of the Consolidated Environmental Law (TUA) is the great importance given to the prevention, production and recovery of waste. The notion of secondary or second raw material is also considered of particular attention. SRMconsist of production waste or materials deriving from recycling processes, which can be re-introduced into the economic system as new raw materials. In terms of the waste hierarchy defined by the Waste Framework Directive (2008/98 / EC), directive on waste and its management, secondary raw materials represent materials and products that can be re -used as raw materials through the simple reuse, recycling or restoration. In the vision expressed by the EU in the new action plan for the circular economy, which is part of the European Green Deal 2030, in a context of circular economy, a development of economic growth that is not connected is no longer conceivable to a rational and proportional use of resources, what is discarded as waste must be recovered and enhanced. The review also asked what role technology plays as a driver and tool for the transition to sustainable waste management. In particular, we discuss the capacity of the blockchain to support political objectives by encouraging sustainable waste management; offer clarity on product and waste property rights; maintain the anonymity and privacy of institutions and individuals. The ultimate challenge is dedicated to the disclosure of results and future prospects.

# Review of the literature

The literature review process highlighted the importance of blockchain technology (BCT*),* which has proven useful in managing the waste cycle and tracking, and in the relationship with the environment. There origin of this technology dates back to 2008 with cryptocurrencies by Satoshi Nakatomo. It has been noted that the blockchain could have a high potential to support the “Circular Economy” (CE ). The CE is defined as a chain recycling strategy that aims to eliminate waste generated in production and consumption , transforming the traditional linear production system into a circular circuit system ( Kirchherr and Hekkert,2017 ) New enabling technologies including the Internet of Things (IoT ),Blockchain technology (BCT) and artificial intelligence (Lasi et al. , 2014) can be useful for implementing the Circular Economy (CE) and sustainable supply chains (Bai and Sarkis, 2020; Kouhizahed et al. , 2020). In particular, the capabilities of cyber-physical systems, IoT and BCT, provide further insights into creating an efficient waste management system (Bharadwaj et al., 2016). The four potential benefits of adopting BCT in the CE, (Esmailian et al. , 2020) are: Greater incentives through the use of tokens that have the function of rewarding those who engage in greener behaviourbehavior; Greater attention/visibility, which allows the manufacturer to monitor and verify the entire life cycle of the product; Improvement of the efficiency of the whole system; Cross network restations . (Esmailian et al., 2020) .

Table 1 - Limits and / or application advantages of blockchain in waste management

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| **AUTHORS / YEAR** | **SCOPE OF APPLICATION** | **LIMITS AND / OR BENEFITS OF APPLICATION** |
| (Gong Y., et *al.*; 2022) | MARINE PLASTIC DEBRIS | It improves the transparency of recycling value chains and makes them more acceptable to the supervision of society and consumers. |
| (Wozniak ME, *et al.;* 2021) | SUPERMARKETS AND DISTRIBUTORS | It ensures reliable, scalable and transparent tracking. |
| (Voorter J. and Koolen C.; 2021) | BUILDINGS | Better data management and leads to a smoother transition to circular practices in the construction industry. |
| (Cheng Y., et *al*.; 2021) | BATTERIES FOR ENERGY VEHICLES | The decentralization and anti-tampering features of the blockchain can guarantee the safety and reliability of the relevant data, realizing the traceability management. |
| (Sahoo S., *et al.;* 2021) | Electronics | Blockchain technology increases accountability, transparency and trust in the system. |
| (Ahmad RW, *et al.*; 2021) | MEDICAL EQUIPMENT | It allows the exchange of information between all the actors involved in waste management in a completely safe, transparent, traceable and reliable way. |

Source: Own elaboration

# Material and methods

The following literature review was conducted through a single database, Scopus, one of the leading multidisciplinary databases for peer-reviewed literature (Geraldi et al., 2011). The choice to use only this database is based on the fact that it seems to be a suitable tool both for searches by the main publishers, including Elsevier, Springer, Emerald, as well as for other publishers (Reim W. et al., 2015). For a selection focused on our study, 22 keywords were employed, using the Boolean variables “or” and “and”. "OR" was used for the nine digital technologies whilst “AND” were used to limit the field of our interest, namely that of waste and the waste cycle. In the first phase of the search, 173 articles were found, refined through practical screening criteria. Conference articles, working papers, commentaries, and book review articles were excluded, and only journal articles were considered (Seuring and Muller , 2008) which were not classified either by bands or by "subject area". Further exclusion criteria of the search were the language, in fact, all the articles written in a language other than English were not considered, the time- span reference is 2015 - 2022, since the starting year coincides with the year of the subscription of the Agenda 2030 program, a development plan for sustainability. Eventually, 53 articles were identified and considered relevant for the analysis. This system resulted in the exclusion of 120 items. All the data extraction, such as authors, title, year, DOI, abstract, keywords, were exported in an Excel text shared with the research group. Of the remaining 53 articles, both quality and originality were assessed, and the cited references were used as research insights.

* 1. **Results and Discussions**

From the following analysis it emerges that the circular economy is based on sustainability which is essentially based on three factors: Economic, Environmental and Social (Purvis et al., 2019). Blockchain technology *(BTC) in the* supply phase chain can help reduce the amount of waste and improve efficiency. The entire path of the waste can be monitored from source to discharge, ensuring transparency and traceability. The underlying principle is to enhance the recycling of materials through collaboration between companies and citizens. With the help of this technology, exchanges are ensured, the authenticity of data and the chronology of the entire supply chain is guaranteed, as well as the certainty of the circularity of the products. The use of BTC plays a central role in business models as it allows the creation of connections in the various processes that follow each other, promoting the emergence of a unique model of waste circularity that brings benefits, increases company profits and contributes to improving environmental sustainability. In fact, there is no single codified traceability model that is applied and shared by all in the same way, its creation could favor the transfer and handling of waste between different countries.

* 1. **Conclusions and future perspectives**

A fully traceable circular economy model, with proposals, interventions and objectives to be achieved, increases the possibility of recovering MPS and using them in different production sectors. However, there are critical factors for operators in the sector regarding the use of secondary raw materials. From the quality point of view, the lack of a common standard at European level leads to uncertainties on the quality of the MPS which makes the sustainability of the recycling cycle difficult. For their commercialization it is necessary to facilitate their circulation beyond national borders, within the EU. n the demand side, in order to create a dynamic market for SPM, public policies are needed to encourage the use of recycled materials in products and, in infrastructure. Finally, the presence of harmful chemicals in the recycling streams has led the European Commission to require the tracking of chemicals. From the perspective of a circular system, in which waste becomes a product / resource, the real challenge lies in technology, especially the blockchain which affirms the transparency, security, traceability and usability of data, enabling the creation of a green transition to the circular economy.

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