Open Market for Reusing Auto Parts with Blockchain

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Abstract. The evolution of technologies in recent years has allowed many advances in various areas, such as robotics, the Internet of Things, Big Data, Blockchain, among others.

These advances have allowed to solve many of the problems we face nowadays, such as today, for example, they have been used recently in the fight against Covid-19 which has affected and continues to affect people and organizations around the world.

Taking advantage of the advancement of these technologies, the circular economy concept has been successfully implemented in various spheres of society and in various countries, with the aim of transition from linear economy ideas (produce, consume, and dispose) to more sustainable models (recycle, reuse, and reduce), keeping products and raw materials in circulation if possible, while adding value for society and business.

In this paper we will address how Blockchain can leverage the ideals of the circular economy, analysing and implementing a prototype Blockchain network in the used car parts market.

The structure of this work is based on bibliographical research that served as a basis to collect data and information relevant to the themes in question, as well as the practical implementation of the concepts in the case of the reuse of used parts.

Keywords: Circular economy · Blockchain · Ethereum network · Open market

1 State of the Art

1.1 Blockchain

The ideas behind blockchain are not new, in 1991, Stuart Haber and W. Scott Stornetta introduced a computational solution for digital documents in a way that that they could not be altered. Because of the ease in which digital easily manipulated, they believed it was necessary to create a "time stamp", i.e. date and time on digital documents, allowing to know the period of changes to them. They believed that, to achieve this, two steps were needed steps:

The first is to find a way to stamp the data without being dependent on the characteristics of the physical medium that stores them, making it impossible to change one

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without changing the other. The second step is to create a way that it is impossible to stamp a document with a date and time other than the original (Haber and Stornetta 1991).

In 2004, Hal Finney created a system that is the precursor to Bitcoin, the Reusable Proof of Work. This system receives "hashcash" as a Porf of Work token, in return it creates tokens signed by the RSA2 cryptographic system, which can be transferred from person to person and exchanged for new RPOW's at each step. Until then, the cryptographies of digital currencies had a major problem of double spending, which was the risk that a coin could be spent twice. The RPOW solves this problem by keeping the ownership of tokens registered on a trusted server.

In 2008, a person or an entity named Satoshi Nakamoto, published an article describing a decentralized digital currency based on peer-to-peer technology and in January 2009 Bitcoin was launched. The most important thing about Bitcoin is that it is a technology that not only has a decentralised system behind it, but all transactions are stored in an immutable ledger, where there is no financial behind it, relying more on the network than a central entity (Satoshi Nakamoto 2008).

The blockchain can be defined as a decentralised network in which transactions take place transactions occur between its members transparently and openly without the assistance of intermediaries (Mougayar and Buterin 2016).

One of the most important components of the blockchain system are Smart Contracts, applications that run on a blockchain network and are a set of rules that help in the process of streamlining transactions.

The concept of Smart Contracts was first introduced by Nick Szabo in 1994 but had a long time in inactivity because there was no platform that could implement these rules. That changed with the creation of Bitcoin and since then, Smart Contracts have gained a lot of popularity and are essential today in any Blockchain network (Mougayar and Buterin 2016).

Swan (2015) states that what makes Smart Contracts different from other types of agreements are the existence of three elements, autonomy, self-sufficiency and decentralisation. Autonomy, means that after start-up, they do not need human interventions. Self-sufficiency means that Smart Contracts have the ability to gather sufficient resources to be able to function, for example processing power processing power. And finally, decentralisation allows these rules to be executed in several nodes in the network.

Another important concept in blockchain technology is the consensus algorithm, allowing different participants to agree to validate transactions that are requested in a blockchain network. Mougayar and Buterin (2016) states that consensus is the first layer of a decentralised architecture such as blockchain; users do not need to know how that algorithm works, despite the dependency, trust and security that it offers. This allows that there are never repeated values in the same transaction.

1.2 Benefits of a Blockchain Network

The benefits of blockchain technology go beyond Bitcoin or other implementations of cryptocurrency. Its applications are many and already help in the resolution of real problems that can be found in the political, social, environmental, scientific, among others.

According to Mougayar (2016) Blockchain brings benefits at the level of cost reduction, greater transparency between the parties involved, less risk in transactions, greater productivity, greater efficiency in solving tasks, higher quality and by consequently, more gains and growth.

1.3 Challenges in Implementing a Blockchain Network

Despite the benefits that can be achieved in the long term mentioned above, Blockchain presents some challenges nowadays. Mougayar (2016) mentions that Blockchain just like so many other technologies will take some time to be widely accepted due to various challenges and barriers, whether technical or human.

The same author cites some factors such as infrastructures in developmental stage, scarcity of skilled human talent, scalability problems, that is, the ability to accommodate increases in users in a network such as Bitcoin, privacy issues, cryptocurrency volatility, initial implementation costs, lack of understanding of the potential of Blockchain, distrust between members of a network, among others.

2 Circular Economy

The current business landscape is changing extremely fast, bringing to the fore new challenges that force organisations to be more adaptive and innovative. With the scarcity of resources, air and sea pollution, and an increased concern about climate change, social actors are becoming increasingly aware of the need to implement sustainable, renewable and long-lasting measures in order to avoid irreparable damage for future generations. Many companies are following the changes in governmental laws and customer's consumption habits, adopting measures such as the use of recycled materials and/or cutting down on the use of plastics.

In this context, the circular economy emerges as a new approach to face the challenges that the current world proposes us, transforming them into added value for the society and business, offering the ability to redesign a positive and sustainable future.

The circular economy offers a new pathway and a new way of making use of used products, extracting as much value as possible through reuse and recycling before they are safely disposed of in nature (MacArthur 2013).

The major goal of the circular economy is to make the transition from the linear economy that is based on the principles of producing, consuming and disposing products to an approach of reusing recycle and reduce in the consumption of materials and raw materials, i.e. keeping products in a looping stage for as long as possible. Essentially, the circular economy eliminates the idea of waste, changing the way we produce and consume, creating a healthy and thriving ecosystem for society and the economy (Lacy et al. 2020).

The same authors maintain that although many efforts have already been made, much remains to be achieved because companies focus more on instant gains and programmes that can be regressed to current business models. They feel that the way to achieve the potential of the circular economy is to underpin it with the technologies of the fourth industrial revolution in ways that capture new business opportunities and strengthen

core businesses. That is, to analyse the waste that is operations, rethink the life cycle of products or services in order to optimise their use and eliminate waste. Another thing to improve is the organisational culture, that is, to root the principles of circularity in the new practices and procedures.

2.1 Benefits of a Circular Economy

The potentials of the circular economy are still being discovered, and although they are limited geographically, it is estimated that the values of savings in consumption of materials and products could be as high as USD 700 billion globally (MacArthur 2013).

According to studies by the Ellen Macarthur Foundation, the benefits of savings can be found on a number of fronts, notably in the UK catering industry, where processing waste in line with the principles of the circular economy principles can generate a profit of $1.5 billion annually, while at the same time providing new business opportunities for local community and investors. The same study mentions that another opportunity can be found in the fashion industry, where clothes at the end of their life cycles can be reused to produce other types of products or recycle the yarns for future production.

Lacy and Rutqvist (2015) state that another benefit of the circular economy can be identified in product packaging. They use the example of the Carlsberg Circular Community, which is an initiative that relies on the creation of future generation packaging bottles optimised for recycling and reuse, while delivering added value and quality to customers. The aim of this initiative is to encourage customers that these bottles are not materials to be wasted, but rather to be reused for a long period of time, in the most correct way possible.

2.2 Challenges in Implementing the Circular Economy

P. Lacy et al. (2020) state that despite the gains made in recent years, there are still barriers that hinder the application of the circular economy still exist. They say that societies culture or habit of consumption, i.e. many people are still attached to the idea of buying, using and disposing of products. For example, smartphones that may have 4 or 5 years of useful life, but the demand for new models and trends, limit the ability to use used parts or sell second-hand products.

Other barriers that hinder the implementation of the circular economy are the policies and regulations of governments in many countries. According to the report “Paving the way for a circular economy: insights on status and potentials” by the European Environment Agency (EEA) countries use regulation basically for recycling, waste management and energy recovery. On the other hand, the ideas of reuse, consumption and green development have fewer demanding rules and are usually just campaign labels (EEA Report, no. 11/2019).

3 Application of Blockchain in Circular Economy

Blockchain and the circular economy are two emerging and disruptive concepts that promise to transform the social, economic and technological lives of social actors.

Kouhizadeh et al. (2020) state that blockchain offers capabilities in the implementation of the principles in various ways, such as transparency of information, verifying the origin of a product and tracking its life cycle as well as showing the users involved in the operations. One of the most practical use of blockchain in the circular economy is the application of the principles of transparency in supply chain management. Participants in this network can track and verify the life cycle of a product from the origin of raw materials to the final manufacture.

The same authors state that despite the advantages already mentioned, the use of blockchain in the circular economy in supply chain management, may bring some drawbacks such as, as the sharing of confidential information of the network members, as well as other information that the members do not want to share.

Another advantage that blockchain offers is the Reusable Proof of Work used in ledgers, which reduce the risks of failure of blockchain networks and cyber-attacks.

But on the other hand, this has a cost which is the power consumption in the computations required (Mougayar and Buterin 2016).

Another difficulty is the lack of exchange of information between companies in a given industry, as these often prefer to focus on their own customers (Kouhizadeh et al. 2019).

The use of blockchain in the circular economy encourages changes in habits and consumer behaviours. This can be achieved through rewards on the purchases of products that build on the ideas of the circular economy. Rewards that can be tokens or cryptocurrencies for customers (Kouhizadeh et al. 2020).

Finally, we can conclude that despite the benefits that can be found in the adoption of blockchain in the circular economy, these two concepts are still nascent and not all successful applications end up serving all sectors of society. It takes a lot of work and engagement among communities, entrepreneurs, governments, and investors to overcome the barriers that prevent the widespread use of circular economy principles based on the potentials that blockchain can offer.

4 Traceability for Blockchain-Based Circular Economy

Blockchain technology allows its authorised users to send data and validate information that cannot be manipulated by anyone. Therefore, when there is a record of the occurrence of an event and the associated data is recorded in the chain, that event is immutable and a record of the event occurrence can be viewed on the allowed networks, based on the agreed privacy settings.

This means that we can reconstruct the entire history of the object in the supply chain, keeping a validated event log available to users with the touch of a smartphone. This functionality is relevant and useful for the recycling of automotive parts and beyond, as it provides a fundamental basis for any verifiable and defensible statement that can be made about products.

If industries are effectively moved from a linear to a circular economy, the interconnectedness of data may be the revelation that catalyses them towards self-perpetuation. Within these new ecosystems, traceability mechanisms and Chain of Custody (CoC) models can substantiate any assertion of content that value chain stakeholders may wish

to make. Points of evidence generated through these models and mechanisms provide evidence that recycled material remains active, i.e. in use as an ongoing resource and not ending up in storage.

While evidence of responsible handling and validated claims is important, traceability important, traceability mechanisms can support insights by connecting data that was previously isolated. When we allocate a digital identity to materials at the batch or component level and trace it through a value chain, we are able to capture information from primary production through use and ultimately its future disposal or reuse.

4.1 Sustainability

By having visibility of all actors involved in the handling of this material, we can gather sustainability credentials and allow primary stakeholders the opportunity to assess and report on their appointed suppliers approach to human and environmental sustainability factors.

The additional transparency of material flows can allow industry and entities to access more data to build reliable life cycle analyses and assess the environmental impacts of a product or value chain with more accurately.

4.2 Efficiencies

Blockchain, can use smart contracts to track and automate transactions without the need for a centralised authority. There is untapped potential to increase efficiency and reduce costs with blockchain applications across industries for their supply chains. The transparency that blockchain offers also supports more data insights into material flows, making it easier to prevent fraud.

5 Traceability for Automotive Parts Chains

To deal with the supply of spare parts the blockchain technology proposes to permanently record all movements, modifications, restorations and ownership details of spare parts in a transparent and tamper-proof distributed ledger. Furthermore, the transparency of transaction records (e.g. frequent component maintenance) increases the trust of customers and regularity authorities. Using immutable transaction records, blockchain technology helps identify counterfeit parts, minimise fraud, reduce component maintenance costs and delays, and establish asset provenance based on the traceability feature. Still, the track and trace service help keep track of a component or document during its shipment.

Validated traceability enables in today's more transparent and responsible economy. What if change could be catalysed by enabling waste producers to connect to second life outcomes, including recycling and beyond? If consumers and industry were given the opportunity to consume their own waste through validated material circularity, perhaps we can improve our current trajectory.

BMW is one of the first groups in the automotive industry to use technology blockchain to improve transparency in its global supply chain, specifically targeting the parts and raw materials procurement segment. To a huge entity like BMW, the use of

blockchain can help optimise its operations and increase traceability in its supply chain, while at the same time ensuring that shared data is tamper-proof. The main objective is focused on providing seamless traceability of components and will provide immediate data transparency.

One of the BMW Group's latest projects, PartChain is to enable the collection of tamper-proof and consistently verifiable transaction data in the BMW's supply chain.

In 2019 BMW started a project to track parts via blockchain, involved BMW's plants in Spartanburg, South Carolina and Dingolfing, Germany, as well as three locations of its supplier, Automotive Lighting. The aim is to achieve complete traceability of raw materials with its suppliers.

6 Case Study

Nowadays, consumption is increasing more and more, reaching extremely of products that are only used once and then thrown away. This effect is due to the increase in people's quality of life and also to the increase in consumers purchasing power.

In this way, the importance of reusing products is gaining more and more space in our lives. Most of the industries have implemented policies of recycling and reuse of products, and in the car parts market the scrap yards are places where they collect used parts and consequently sell them at lower prices than at the manufacturers.

The job of the scrap yard is to collect end-of-life vehicles, dismantle and store the parts that can still be reused, so that they can later sell them second-hand at a lower price than a new part would cost. In this sense, they practice a circular economy model, where they reuse products that are practically thrown away or that are at the end of their life.

Although prices are lower for second-hand items, the present system of selling used parts brings many uncertainties to the final consumer. This is notably due to the fact that there is no guarantee when purchasing the product, lack of information uncertainty of the condition of the part and its origin are the main disadvantages that of second-hand products today.

The studies around Blockchain technology have been growing in the last years, presenting revolutionary results in various markets and departments. An implementation of this technology in the used parts market will bring more transparency, information and trust to the final consumer, and as a consequence, the practice of stimulate the practice of circular economy in various entities of this industry.

6.1 Blockchain Applied to the Case Study

The car scrapping centres, or the so-called scrap yards have been the subject of several polemics, many entities operating illegally are pointed out as an environmental problem, processing the parts incorrectly, polluting and damaging the environment. Moreover, the demand for second-hand parts has generated a lot of uncertainty by the consumer at the time of negotiation, the lack of guarantees by the seller, results in an obstacle in the evolution of circular economy in these entities.

The implementation of Blockchain architecture in this used parts market would be the resolution of the problems previously reported. In this way, the acquisition process

of a second-hand part will be transparent and secure, generating more trust and value information at the time of purchase. It would be impossible to manipulate and change the information about the origin of the piece. Furthermore, the constant verification on the part of the brands that produced the pieces will facilitate the auditing process by other entities.

Since this is a project based on the circular economy methodology, the whole process of validation and acquisition of used parts will have two types of verifications. Each time that a person wants to get rid of an old car, he will have to deliver it to a certified entity, this transaction will be verified by the public institute for modality and transport that is part of the indirect administration (IMT) in order to be able to cancel the registration and stop paying taxes on the vehicle. Then, the car will be disassembled, and the parts will be registered in the Blockchain, where the brands themselves will validate the information such as serial number, year of production and the type of the part.

This system of validating information on used parts allows greater transparency for the end consumer. On the other hand, scrap shops and workshops, which will implement the Blockchain architecture will automatically become certified entities, where they will be able to sell parts above the normal market average (Table 1).

Table 1. Comparison between traditional processes and Blockchain processes.

Current process	Blockchain process
Lost information - In huge second-hand markets, scrapyards and workshops, customers do not know the origin of the parts, their actual condition	The pieces will be related to their origins, whether they are white label or parts that have never been altered since the year of manufacture of the car. The brands that produced the parts will have to validate information such as part type, year of production and serial number
Non-certified entities - There are scrapyards and workshops operating illegally polluting the environment	All entities will be automatically certified, increasing the quality of their services and consequently the demand
There are stolen cars that are dismantled in scrapyards and illegal workshops, where they are later sold for parts in second-hand markets	With the IMT entity as the validator of ownership, nobody will be able to deliver a stolen car to be sold for parts
Illegal scrap shops that dismantle cars have no authority to cancel a registration. This way people risk losing their car and continue to pay the Single Road Tax. circulation tax	The registration of ownership will be automatic passed to the scrap yard or workshop certified
A process with many polemics and little valid information	Transparent and safe process

6.2 Implementation

After analysing our case, what implications it would have to bear, we moved on to the implementation phase. To implement this solution, we establish the different nodes and actors of our Blockchain network and represented the actions between them.

Nodes: Workshops and Scrap Metal.

Actors: Workshops and Scrap Metal, IMT, Brands, Customer (Fig. 1).

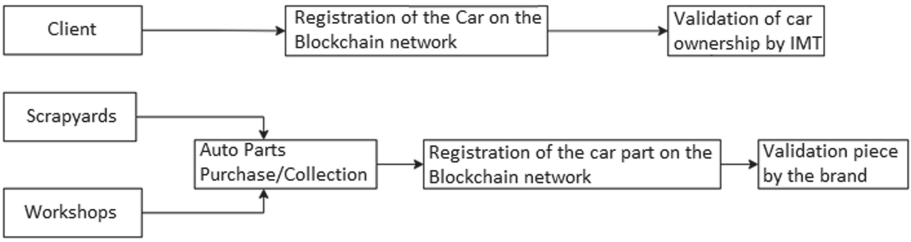

Fig. 1. Information flows.

As we can see in the previous figure, the goal of our Blockchain network is to allow in a sustainable way the reuse of the different parts of the different cars according to a circular economy concept.

Initially the user requests the registration of his car before the validator entity that in this case is the IMT. With this registration the client can later sell his car so that the parts in good condition and viably functional can be used and reused. This IMT registration also allows to guarantee the ownership of the vehicle, so that someone doesn't try to sell a stolen car.

Regarding the scrapyards and workshops, they can opt for the purchase process of the parts that a particular car includes. The parts are collected and registered on our Blockchain network. All this data is then validated by the brand so that no one tries, for example, to insert adulterated parts.

6.2.1 Implementation Objectives and Requirements

The following objectives and requirements have been defined for the functional application of our Blockchain network:

1. Allow the input of information about cars and parts in a secure and transparent way.
2. Automatic registration of ownership.
3. Creation of validating entities that confirm the veracity and integrity of the information.
4. Traceability and origin of all cars and their parts.

6.2.2 Tools and Technology Used

We use Ethereum technology to implement our solution. Ethereum is a decentralized platform capable of executing smart contracts and decentralized applications using blockchain technology.

For the development of smart contracts, we used the Solidity language. This high-level language was created with the intention of allowing the implementation of smart contracts that guarantee and govern the behaviour of our Blockchain network.

The following image illustrates the architecture of our system (Fig. 2):

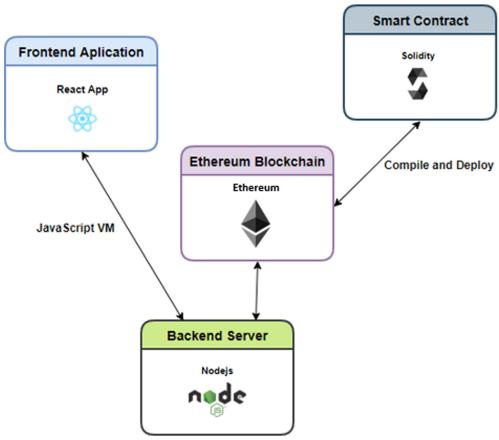

Fig. 2. System architecture.

6.3 Smart Contracts

6.3.1 Smart Contract Cars_BC

Before explaining the reason for implementing this Smart Contract, it is first, important to clarify and define what information our Blockchain network will contain about each car.

The following figure lists the data that the contract will contain and which methods existing (Fig. 3).

This smart contract will contain all the data about the car in question, such as brand, model, engine, and serial number, it will be possible to input all this information into the Blockchain network.

Add Car() Function: Function that allows adding a new car to the Blockcahin network. For this, it is entered data such as the brand, model, engine, other fundamental about the status and ownership of the vehicle. In this transaction is also registered the current owner of the car that is obtained through the "address" present for the user in the network (Fig. 4).

Function Validate_IMT_Car(): Function that allows to supply the supplied information. In case the information is correct, true is returned. If the information is incorrect false is returned. In this case the validating entity is the IMT, and this has its own address that allows distinguee of all other actors of our Blockchain network.

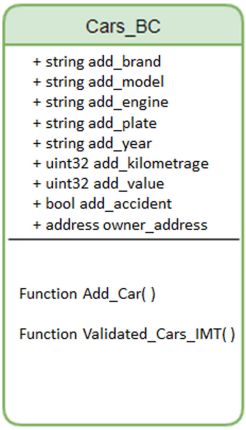

Fig. 3. Smart contract Cars_BC

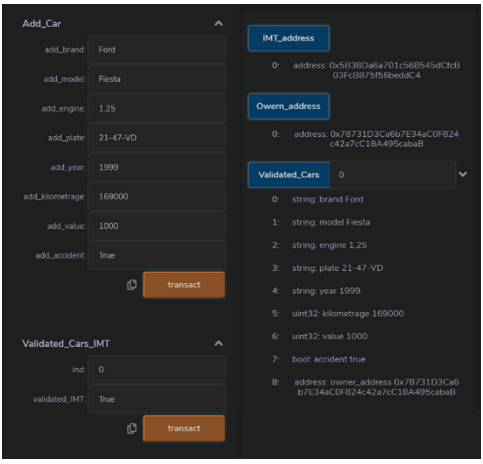

Fig. 4. Function Add_Car().

6.3.2 Smart Contract Parts_BC

As was the case with the smart contract for cars, for parts the method and implementation thinking were similar. The aim is that consultation and information about the different components of each car and that this information is validated by a trustworthy agent, which in this case was chosen to be the brand itself (Fig. 5).

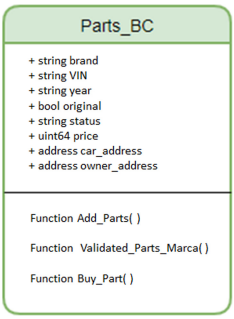

Fig. 5. Smart contract Parts_BC.

AddPiece() Function: Function that allows adding a new piece to the Blockcahin network. Are the different data of the piece are entered as the brand, model, engine and other fundamental data about the state and characteristic part. In this transaction is also registered the owner_adress that allows to enter the current owner of the part (Fig. 6).

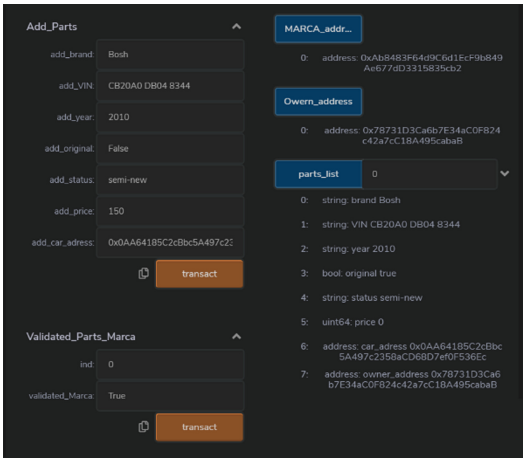

Fig. 6. Function Add_Part().

Function Validate_Mark_Piece(): As it happened previously for the case of the car this function allows to validate each one of the pieces through a Boolean variable (True/False). The integrity of this information is performed by the brand through its address in our Blockchain network.

Function Buy_Parts(): Method invoked when a transaction occurs in which the owner of the auto parts is changed. Using the msg.sender function, the address of the caller of this function is obtained and the information is updated in the Blockchain network.

6.3.3 Smart Contract Deploy Contracts

This contract has the function of allowing the 'deployment' of the remaining contracts, i.e., it can be seen as the contract that triggers the first block of our blockchain network. This first block in a Blockchain network can be configured using the genesis.json file and allows different configuration parameters to be set.

In this case the Cars_BC and Parts_BC contracts are created and invoked and added to a list of implemented contracts (Fig. 7).

Fig. 7. Smart contract deploy contracts.

7 Conclusion

The main objective of this work is the connection of blockchain technology with the concept of circular economy. The model was implemented for a car scrapping network, including scrapyards and workshops, where used parts will be registered and reused by consumers. The demonstration part allows used parts to be added to the network associated with its original car, facilitating access to information for both consumers as well as producers and suppliers.

When implementing this project, we identified a number of possible improvements that blockchain could bring to today's societies. Knowing the life cycle life of products and their origins, consumers will have a greater motivation to practice the concept of the circular economy in their daily lives.

Based on pillars such as accessibility, reliability and immutability our work above all aim to encourage society to think outside the box and no longer third parties simply to certify a fact and encourage the community to develop self-sufficient and scalable solutions.

However, technologies like Blockchain have challenges to be optimized as high consumption of energy spent for its operationalization, as well as mistrust of actors and competition with other business models.

However, we are sure that the application needs improvements to be adapted to the real context, but our main intention is to generate debate on the important circular economy, a disruptive issue in itself, allied to blockchain aiming at having a big impact in the in the next years in the way we live, think and consume products.

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Data Availability. Link to the implementation: https://github.com/ddces-iscteiulpt/Blockchain-CircularEconomy-2021.git.

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