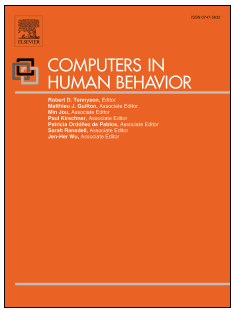

Blockchain technologies to address smart city and society challenges

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Abstract

New Information and Communications Technologies (ICT) are changing the way in which the world works. These technologies provide new tools to face the issues of contemporary society (poverty, migrations, sustainable development challenges, governance, etc.). Among them, blockchain emerge as a disruptive technology able to make things in a completely different and innovative way. They can provide solutions where before there were none. Recently, these technologies have become subject of intense research and development by industry and academia. In consequence, a large amount of interesting works is published in many areas, proposing solutions, services, frameworks and applications based on these technologies. The research focusing on the previous challenges are especially interesting in current society. However, the proposals arrive at higher speed than society can assimilate them, and sometimes they are not properly exploited. Thus, this paper provides a comprehensive overview of the blockchain technology to identify what are its key attributes that enable to successfully address the social challenges. The review has been conducted from three point of views: service-delivery, resource-management and city-administration, and has been focused on the Sustainable Development Goals of the United Nations, in order to cover the full agenda of current social issues. The contributions of this work are an exhaustive compilation of the existing research on blockchain technology to tackle the social challenges from several angles, and the identification of the key features and the conditioning factors of the practical applicability of the technology.

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New Information and Communications Technologies (ICT) are changing the way in which the world works. These technologies provide new tools to face the issues of contemporary society (poverty, migrations, sustainable development challenges, governance, etc.). Among them, blockchain emerge as a disruptive technology able to make things in a completely different and innovative way. They can provide solutions where before there were none. Recently, these technologies have become subject of intense research and development by industry and academia. In consequence, a large amount of interesting works is published in many areas, proposing solutions, services, frameworks and applications based on these technologies. The research focusing on the previous challenges are especially interesting in current society. However, the proposals arrive at higher speed than society can assimilate them, and sometimes they are not properly exploited. Thus, this paper provides a comprehensive overview of the blockchain technology to identify what are its key attributes that enable to successfully address the social challenges. The review has been conducted from three point of views: service-delivery, resource-management and city-administration, and has been focused on the Sustainable Development Goals of the United Nations, in order to cover the full agenda of current social issues. The contributions of this work are an exhaustive compilation of the existing research on blockchain technology to tackle the social challenges from several angles, and the identification of the key features and the conditioning factors of the practical applicability of the technology.

Keywords.- *Blockchain, cryptocurrencies, e-government, quality of life, SDGs, smart-city*

1. Introduction

Recent technology advancements are transforming the world we live in. Today, there are many aspects of our daily life that have been affected by changes promoted by technology that involve how we communicate and relate among us, how we acquire information from the world and how we interact with the society (Fukuda, 2020; Roztocki et al., 2019).

The whole society has evolved thanks to the technology, and today we have new tools to address the contemporary society challenges, such as poverty, migrations, sustainable development and governance, among others.

As protagonists of this transformation cities are increasingly becoming the lab where several technology applications take place in order to get greater efficiency with regard to available resources, to advance in sustainable development and to create accessible environments (Pérez-delHoyo et al., 2017). In short, cities evolve towards 'smart' cities by adding technology solutions with the ultimate goal of increasing the quality of life of citizens.

Blockchain represents an outstanding example of disruptive technology with greatest potential impact in the near future (Mora el at, 2020a). They can provide innovative solutions for governments close to the citizens. In fact, the introduction of the technology in government is very related to the future of cities as first level of public administration.

The characteristics of blockchain are well known by the community, consumers and business (Mendoza-Tello et al., 2019; Choo et al., 2020; Rehman et al., 2020). The key special features they provide can be summarized as follows:

-*Immutability of information*: the information stored can't be changed or altered without the consent of the actors concerned. Thus, instead of relying on a centralized authority (central bank, administrator or organization), it ensures the integrity of data through a collection of nodes.

-*Distributed trust*: the information is maintained in a distributed fashion by all users on the system. It is needed a consensus among nodes to help the network make decisions. This consensus, supported by cryptographic algorithms, is responsible for the system being trustless.

These key features provide confidence among anonymous participants without needing any middleman or broker who care, supervise or authorize the transactions. Based on them, a lot of innovative applications can be designed. For example, the ability to create cryptocurrencies, such as bitcoin, computerized contracts for exchange, assets, goods and services, such as smart contracts, etc. Supported by these qualities, these technologies are able to address challenges that until now could not be solved in an efficient way.

In this regard, there is an intense work of creative research by different stakeholders and academia who are proposing a large amount of interesting solutions for many application areas. However, many times the solutions are focusing on a specific use case, and no apparent relation between its technological capacity and the potential to address challenges in other fields can be found.

Motivated by that, the **aim** of this work is manifold: The first one is to collect and organise these contributions in order to show the possibilities of the blockchain technology oriented to improve the society. Secondly, based on the previous examples, this research seeks to identify what are the key attributes of the technology that enables to successfully address the challenges. And finally, to draw the border of knowledge of this technology in order to outline the open research lines which allows to enhance its capacities and improve its performance.

The review and classification of the solutions is made from three point of views according to the subject to which the technology can be oriented: service-delivery, resource-management and city-administration. The first two groups of proposals are directly related to the social development challenges, and the third collects the proposals to address the social issues within the municipal level since the city is the most important ecosystem where the citizens live and where the technology is already playing a key role

In this regard, the Sustainable Development Goals (SDGs) of UN (United Nations, 2020a; United Nations, 2020b) is used as main guide to classify the challenges and solutions described for the first two groups. This represents the framework of actions by all countries to promote prosperity while protecting the planet (United Nations, 2020a). Assistance in solving social problems and support for vulnerable groups is a priority for today's society (Barrientos, 2010; Stukach et al., 2019). Social policies and services seek to promote social cohesion by supporting the most vulnerable citizens to live a dignified life, while promoting their potential, productive capacity and participation in society (Addison et al., 2015; Barrientos, 2010; Misuraca et al., 2016). However, creating a strong social policy that delivers positive results in the development of vulnerable societies and groups is a common real challenge for governments and public administrators (Addison et al., 2015). The variability of the general context of each country, conditioned by economic, cultural and political factors and the specific needs of its citizens (Tangcharoensathien et al., 2017) determines the complexity of the problems, which tend to be multidimensional in nature, including factors such as demographic growth and population ageing.

Under this approach, we intend to highlight the potential of blockchain technology to address these challenges by describing representative solutions of each of them as a sample of what blockchain is able to do to provide innovative solutions for the society.

The **methodology** used to conduct this research is mainly based on a literature review which involves a synthesis of the findings and other key aspects stemming from the existing research studies and applications of the blockchain technology. The analysis of the knowledge compiled allows us to derive a taxonomy of the proposals, and the characteristics of the technology that make possible the disruptive change.

The **novelty** of this work lies in the combination of the

blockchain technology to conduct an updated state_of_the_art of research about the application of this technology to address the SDGs and city challenges. To date, this is the first critical review focused on matching the issues around the society and a smart city ecosystem, and the solutions to address them based on using blockchain.

The type of solution in each case shows how the initiatives identified are being applied as technological solutions able of promoting social welfare. These are included in this classification:

-*Services*: they seek to respond to a problem and are offered to a specific group.

-*Architectures*: Initiatives that involve an entire infrastructure and a combination of various technologies to make the solution functional.

-*Cryptocurrencies*: Solutions that address a problem through the exchange of digital assets.

-*Models*: Proposals that study at a theoretical level the viability of an initiative, but which are still at an initial stage.

The remainder of this paper is structured developing each point of view of the review: section 2 identifies the main social problems from the point of view of the service-delivery; section 3 describes the contributions from the point of view of the resource-management; section 4 focus on the proposals for city-administration as technology implementation scenarios, section 5 provides a discussion of the findings and raises the new problems emerged with the application of these new technologies; and finally, section 6 draws the main conclusion and propose future research lines to further develop of this technology and its applicability.

2. Service-delivery approach

This level mainly addresses the set of social citizen-centric issues that in some way rely on the quality of service-delivery to the population. Next, some representative use cases of this technology to face the social challenges are described. These proposals have been organized according to the SDGs and targets proposed in the UN Agenda for Sustainable Development (United Nations, 2015; United Nations, 2020a) in order to show solutions to make effective "*Transforming our World*". For each proposal the type of solution is specified. Table 1 summarizes the proposals for service-delivery.

Goal #1 – No Poverty

Blockchain has made it possible to promote many initiatives aimed at fighting poverty. In the case of land ownership, Blockchain has played a key role in managing the records and determination of ownership in an inclusive, transparent, secure, and reliable way. Due to these characteristics, the ownership of a parcel of land can be easily determined and the transfer of ownership or right of use can be accomplished in less time and in a cost-effective way (Kshetri & Voas, 2018; Shang & Price, 2019; Daniel & Ifejika Speranza, 2020).

Initiatives are available that seek to address poverty through financial inclusion, Blockchain facilitates the exchange of economic assets and micro loans, offering products and services suitable for each person and allows to create a reliable credit history (Barrutia et al., 2019; Schuetz & Venkatesh, 2020). (Ammous, 2015) proposes a model of micro-lending from developed countries to entrepreneurs in developing countries, this cooperation is not possible in the context of conventional money transfer methods due to the high costs involved.

In the context of social welfare, new tools have emerged that make it possible to manage processes that until now were very difficult to address or required a lot of resources. Disberse is an organization that oversees receiving donations in conventional money and distributing it through cryptocurrencies to NGOs. Donors are provided with tools for detailed tracking of donated funds. (Reinsberg, 2019a). (Wen-kai, 2020) proposes a model to facilitate the efficient identification of vulnerable and needy populations and manage the follow-up of their situation, thereby reducing administrative costs and efficiently managing the funds available for social development. (Koniyo & Sudarma, 2020) describe a service related to effectively tracking people who receive social benefits from the government, which facilitates the evaluation of how the quality of life of the beneficiaries improves.

Goal #2 – Zero Hunger

Blockchain is being used in the humanitarian sector to monitor supply chains for the distribution of food to vulnerable people, displaced persons and victims of violence (Kshetri & Voas, 2018; Unicef, 2018).

There are also proposals that allow consumers to know first-hand the supply chains and practices used by companies to produce their products (Kim & Laskowski, 2018), this consumer control can promote ecological practices, such as cover crops, crop rotation, agroforestry and rotational agriculture. (Howson, 2019).

Goal #3 – Good Health and Well-being

One of the current challenges in the healthcare sector, is to strengthen methods of protecting and accessing information, as well as achieving high standards of patient privacy and confidentiality. Blockchain is being used to address this security and privacy challenge in the secure exchange of healthcare data between relevant entities (Rupasinghe et al., 2019).

Another challenge is the efficient management of the cold chain and vaccine supply chain, where the complexity of the process and the number of players involved causes many vaccines to lose their efficacy. (Unicef, 2018) estimates that between 50% and 60% of vaccines lose their efficacy while in transit. Blockchain can contribute to improve the ability to manage and control cold chain and supply chain related operations (Unicef, 2018).

Goal #4 – Quality Education

In the education sector, there are initiatives that seek to take advantage of the features offered by Blockchain. Technology has been used to reliably manage and deliver content related to learning courses, promoting accessibility to learning materials contributes to achieving equal access to all levels of education and vocational training for all individuals (Martins et al., 2019).

Also, the trust provided by technology has made it possible to think of solutions that provide decentralized mechanisms to manage the grading process and the granting of virtual diplomas that can confirm the completion of one or more courses (Martins et al., 2019).

Goal #5 – Equality and social exclusion

Blockchain stands out as a technology capable of contributing to the achievement of SDG 5, to renew the role of women, children and gender minorities (Thylin & Duarte, 2019). In relation to finance, Blockchain is used both, to finance projects that promote the rights of women, children and gender minorities (Kamath, 2018), and to empower women and significantly reduce their vulnerability through mechanisms that allow them to manage their money (Blakstad et al., 2018; Thylin & Duarte, 2019). Also, it is possible to use cryptocurrencies as a means to obtain alternative financing, to have safe and secure savings. (Blakstad et al., 2018).

Goal #6 – Clean Water scarcity and sanitation

Blockchain has managed to integrate very well in the processes related to donations for social benefit projects, allowing the management of donations made to charitable organizations through a Blockchain network, which ensures that all operations are transparent, promoting trust in citizens. (Lapointe & Fishbane, 2019).

There are organizations such as thewaterproject.org, an NGO that promotes water projects in sub-Saharan African communities, enabling people to gain access to safe drinking water (Darilek, 2020); and charitywater.org, which promotes the development of projects that provide clean water to communities in need (Saleh et al., 2019). These organizations are exploiting the opportunities created by Blockchain to engage citizens in fulfilling their commitment to inclusive and sustainable water management. Thewaterproject accepts donations through cryptocurrencies, which allows the donor to transfer money directly to the organization without the use of any financial intermediary, significantly reducing transaction fees and times (Darilek, 2020). Charitywater has created a set of tokens called Cleanwatercoin, which aims to help fund the work of the NGO, with each transaction made by users using cleanwatercoin, an automatic donation of 0.1% is made (Saleh et al., 2019).

Blockchain is also being used for autonomous water management in irrigation communities, (Bordel et al., 2019) describes a method of water control for communities that depend on agriculture and where they must share a source or quota of water, the model uses Blockchain to record the amount of water used, so people who need the resource now have a means to trust the system and other members of the community.

Goal #7 – Affordable, reliable, sustainable energy

Blockchain is providing solutions for the energy market, streamlining transactions of energy generated in a community, balancing the supply and demand of electricity and offering the residents of a community more options to choose their energy sources, including renewable energy sources, which is cheaper, cleaner and more sustainable (Orsini et al., 2018). In this sector, cryptocurrencies are playing an important role, promoting the use of Blockchain-based solutions (Johnson et al., 2015), (Mihaylov et al., 2014).

SolarCoin (Johnson et al., 2015) and NRGcoin (Mihaylov et al., 2014) are cryptocurrencies created with the idea of functioning as a reward for small solar energy producers, the aim is to offer blockchain-based tokens to producers, which can be traded as a cryptocurrency, thus promoting the production of solar energy in a verifiable way. KWHCoin (Johanning & Bruckner, 2019), is another example of cryptocurrency, which allows residents of a community to purchase renewable energy from a local generation source, reducing losses and minimizing costs, allowing citizens to have the freedom to choose their energy suppliers.

Goal #8 – Decent Work and Economic Growth

There are some solutions available for consumers to track, monitor and evaluate the human workplace and the human supply chain, the strategy is based on using consumer pressure, that is increasingly interested in the practices that companies use to produce the goods and services they offer (Kim & Laskowski, 2018). Sladefreetrade (Kamath, 2018) is a platform that helps consumers learn about products sourced from the sea and whether they are sourced without exploitative labor practices or modern-day slavery. The platform allows workers to describe their working conditions on a Blockchain network anonymously. Everledger (Francisco & Swanson, 2018) is a platform that allows the tracking of diamonds through a Blockchain network, each diamond is assigned a digital passport. Consumers can be assured that the jewelry is authentic and has been sourced using ethical practices, dignified working environments and from regions free of conflict and forced labor.

Other types of initiatives are aimed at enabling micro credits, focused on small and medium local entrepreneurs, with this solution, entrepreneurs not only expand their possibilities by accepting cryptocurrencies as a method of payment, but also have access to financial services that are hardly available in traditional banking services (Barrutia et al., 2019).

Start-up Etherisc (Kim & Laskowski, 2018). uses blockchain to provide decentralized insurance aimed at helping farmers in developing countries. A land worker can insure his plantations by paying small monthly payments. In case of detecting phenomena that could affect the insured's plantations, the Smart Contracts-based platform makes disbursements of money, this process is done automatically and without the insured's request, all disaster information is obtained from government agency

publications.

Goal #9 – Industries, innovation and infrastructures

Use cases have been identified that use Blockchain to promote small industries, local businesses, and other enterprises, especially in developing countries to access affordable financial services and credit. (Barrutia et al., 2019) describes an economic model to facilitate micro-financing through cryptocurrencies to promote the development of small and medium-sized entrepreneurs. Blockchain allows us to think of opportunities that would be unfeasible to take advantage of with traditional models, for example, (Ammous, 2015) proposes a model that allows citizens from developed countries to make small loans of money to entrepreneurs and business people in developing countries, all managed by a Blockchain network. These types of loans are not possible with the traditional banking model, as making the loan and each repayment would involve a transaction cost equal to or greater than that of the transaction itself.

In the energy sector there are initiatives such as the KWHCoin cryptocurrency, which ensures that small companies participate in the market, reducing costs, using sustainable practices and boosting the local economy, citizens can now decide what will be their source of energy supply (Johanning & Bruckner, 2019).

Goal #10 – Inequality

Blockchain brings solutions to empower social, economic and political inclusion of all people. Bitpesa is a platform implemented in Kenya that allows people to make transactions. The platform receives remittances in Bitcoin and pays the equivalent in local currency (Ammous, 2015). Bitso is a virtual currency that promotes financial inclusion through e-commerce in Mexico, offering lower transaction costs. The platform can be used by a wide range of citizen profiles, from investors interested in the project to people who do not have bank accounts or credit cards (Zbinden & Kondova, 2019). Cryptocurrencies also promote more citizens to participate in the process of social, economic and political inclusion for all. Adapting Blockchain to the domain of social entrepreneurship, allows donors to have better control over how their money is used, the levels of transparency that are achieved, positively impacts the trust of citizens in social organizations and the work they do (Jain & Simha, 2018).

The BanQu economic passport allows the most vulnerable people to obtain a digital identity. A series of data can be linked to this digital identity, such as training completed, financial history, income from remittances, among others. This history can be used as proof of eligibility for employment opportunities, health care and financial services (Kshetri, 2020). Another solution identified is the one implemented by the Estonian government, which provides migrants and refugees with an emergency digital ID based on blockchain, this solution also allows to allocate financial aid, so the degree of vulnerability of the benefited people can be reduced considerably (Scott et al., 2017).

Goal #11 – Sustainable transport

The Etherisc insurance start-up addresses the challenge of significantly reducing economic losses caused by natural disasters, with a focus on protecting small producers and people in vulnerable situations (Kim & Laskowski, 2018).

The Brooklyn Microgrid platform allows citizens to have access to adequate, safe and affordable electricity services from a variety of local sources, helping to balance the supply and demand of electricity (Orsini et al., 2018).

In the mobility domain, the FairBike initiative is a platform based on Ethereum that allows bike sharing, each bike acquires a digital identifier with which it can collect its own money, which can then be reinvested in maintenance or in buying another bike. This initiative allows citizens to have access to a useful, efficient and environmentally friendly means of transport (O'Hara, 2018).

Goal #12 – Waste Management

Blockchain traceability makes it possible to establish mechanisms to ensure that the products we consume are produced responsibly, for example, in Arkansas, a proof of concept has been conducted that allows monitoring meat products. Through QR codes, customers can verify the quality of the meat, this information is stored in a Blockchain network, the consumer's ability to verify can promote the use of sustainable practices such as micro-breeding and herds and hormone-free pasture feeding (Kim & Laskowski, 2018). Also, the Provenance platform is available, which allows companies to communicate to consumers their production practices and the origin and impact of their products., providing information on the production and supply chain (Kim & Laskowski, 2018).

Control in the supply chain also addresses the challenge of reducing food loss while in transit, the StaTwig solution (Unicef, 2018) is using blockchain technology to create an efficient food distribution supply chain. As resources traverse different segments of the supply chain, quality and other vital information is recorded on a Blockchain network. This data is distributed, decentralized and thus establishes trust, transparency and authenticity in these supply chains.

Goal #13 – Climate action

Blockchain-based solutions seek to address the problem of climate change by enabling public participation, Regen Network (Howson, 2019) promotes the sponsorship of regenerative land use practices, with this initiative it is expected that citizens can contribute to minimize the impact caused by climate change. Another use case is the tokenization of carbon credits, with which citizens can offset carbon emissions from a variety of products and services (Howson, 2020b).

Poseidon is a start-up that has developed a platform that finances the environmental cost required to produce and purchase a good or service. The funds raised are used to finance projects that promote positive climate action. The platform uses Blockchain for transparent micro

transactions and artificial intelligence to calculate the environmental cost of a good or service (Howson, 2019).

Goal #14 – Life below water

Fishcoin is a cryptocurrency that seeks to incentivize data recording by small-scale fishermen in the Global South by offering tokens redeemable for credit as an incentive to share data on a blockchain network, Quality data allows regulators to have better criteria to make decisions (Howson, 2020a).

Another initiative identified is Cryptocorals, it is a game that uses blockchain and aims to save coral reefs, people can buy a virtual coral or CryptoCoral, which allows funding projects that are focused on protecting coral communities, the platform is able to provide evidence backed through Blockchain of the positive actions achieved (Fraga-Lamas & M. Fernández-Caramés, 2020).

Goal #15 – Life and Land

Regen Network (Howson, 2019) contributes to the restoration, conservation and sustainable use of terrestrial ecosystems by sponsoring the use of good practices, such as rotational crop planning, for the regeneration of soil quality, the progress made is recorded on the network to inform sponsors.

Scientists at the Canadian Cattle Genome Project foundation propose Blockchain as a method to create a reference library of genetic markers, with free access to a registry of functional traits such as fertility, health, and calving ease. Dairy farmers can make more sustainable breeding decisions. (Kim & Laskowski, 2018).

Blockchain también está aportando de forma innovadora para rastrear áreas de madera y bosques. El objetivo es permitir un seguimiento transparente del origen de la madera. La capacidad de control que la ciudadanía logra en este proceso promueve el uso de prácticas éticas y manejo forestal sostenible (Figorilli et al., 2018).

Goal #16 – Peace and Justice Strong Institutions

Use cases have been identified that demonstrate that Blockchain has the potential to contribute in the fight against violence and vulnerability. Among the mechanisms available is that of providing digital identity. Through a blockchain network, personal data can be stored and managed securely, such as birth registration, vaccination registry, voter registry, refugee registry, national identification card and other metadata (Kshetri, 2017b; Kamath, 2018; Haddouti & Ech-Cherif El Kettani, 2019). The availability of these data can allow a person to access public services and assert their rights, for example, in Moldova, an initiative has been developed that seeks to systematically tackle human trafficking, with special emphasis on undocumented children (Lapointe & Fishbane, 2019). Also, the Estonian government uses Blockchain-based digital identities to reduce the vulnerability of refugees and asylees, while promoting their economic independence since the tool also works to deliver cash aid (Scott et al., 2017).

On security issues, (Leite & Albuquerque, 2020) describe a model that allows the auditability, authenticity, security, availability, verification of integrity and confidentiality of the files used in the field of investigation units and anti-crime intelligence through blockchain structures. Another example is proposed by (Khan et al., 2020), which aims to guarantee through a reliable blockchain-based mechanism the authenticity of the data generated by surveillance cameras. (Heston, 2017) proposes a model for registration, control and distribution of firearms based on blockchain structures. The objective is to promote the improvement of policies related to the use and possession of firearms and gradually reduce interpersonal violence and suicides.

Goal #17 – Partnerships for the goals

One of the current priorities is to improve cooperation in science, technology and innovation, it is also necessary to increase knowledge sharing, as has been verified in all the use cases identified in this section, to bring to reality many of the initiatives, it has been necessary the collaboration of various entities, including governments, NGOs, Startups, among others. One example is the event organized by UN Women, in partnership with the UN Office of Information and Communications Technology and Innovation in Norway, which allowed for discussion and exploration of blockchain-based solutions to address the challenges of protecting women and girls in humanitarian environments (Thylin & Duarte, 2019).

Table 1.
Solution proposals for SDGs based on blockchain technology, from the service-delivery point of view.

SDG GOAL/Target	Initiative	Novelty (type of solution)
Goal #1 – No Poverty		
1.4	Land rights (Kshetri & Voas, 2018; Shang & Price, 2019)	Method to secure property rights and greatly reduce the difficulties and costs associated with the registration process (service).
1.4	Land rights and management (Daniel & Ifejika Speranza, 2020)	Model for managing the exchange of land rights, addressing the problems of trust that exist between landowners and small farmers through land markets (model).
1.1 1.2 1.4	Micro loans from developed countries (Ammous, 2015)	This model aims that entities and individuals from developed countries can make small transfers of money to entrepreneur people in poor countries (model and cryptocurrencies).
1.1 1.2 1.4	Financial inclusion (Schuetz & Venkatesh, 2020)	Model to facilitate the delivery of economic assets through mobile applications, reducing costs and transaction delay, offering appropriate products and services and with the ability to create a reliable credit history (model and cryptocurrencies).

1.1 1.4	Financial inclusion (Barrutia et al., 2019)	Model to facilitate micro-financing to promote the economic development of small and medium-sized entrepreneurs (model and cryptocurrencies).
1.1 1.2 1.3	Control and optimisation of resources for social development (Koniyo & Sudarma, 2020)	Follow up on families who have received social assistance and to verify the effectiveness of social programmes (service).
1.1 1.4	Low-cost micro-lending service (Guo et al., 2018)	To offer a low-cost micro-lending service that seeks to alleviate poverty through financial inclusion (model and cryptocurrencies).
1.1 1.2 1.3	Control and optimisation of resources for social development (Wen-kai, 2020)	Model to facilitate the efficient identification of vulnerable and needy populations, the reduction of administrative costs and the effective management of funds to promote social development (model).
1.3	Disberse (Reinsberg, 2019a)	Service for distributing funds to the different NGOs in a transparent, quick and economical way (service and cryptocurrencies).
Goal #2 – Zero Hunger		
2.1 2.2	Food supply for refugees (Kshetri & Voas, 2018)	It allows beneficiaries to receive cryptographic vouchers to be exchanged for food in local shops, using biometric scanners installed in the shops (architecture).
2.1 2.2	Supply chain (Unicef, 2018)	This solution guarantees the control of the food supply chain through blockchain, efficiently connecting all stakeholders and reducing the rates of expired food during distribution (architecture).
2.4	Regen Network (Howson, 2019)	Allows individuals to sponsor land stewards for promoting environmentally friendly practices. (service).
2.3 2.4	Grape supply chain (Kim & Laskowski, 2018).	Consumers can now learn about the production, orchard treatment and supply chain of South African grapes (model).
Goal #3 – Good Health and Well-being		
3.d	Early warning and reduction of risks caused by falls in older adults (Rupasinghe et al., 2019)	Blockchain is proposed as a technology capable of addressing today's security and privacy challenges in the exchange of healthcare data (model).
3.8	Supply chain StaTwig (Unicef, 2018)	The problem of fragmented vaccine supply chains means that a great number of vaccines become ineffective, Blockchain technology is used to effectively control vaccine handling in the supply chain (architecture).
Goal #4 – Quality Education		
4.5 4.a	Intelligent ecosystem for learning and inclusion (Martins et al., 2019)	Blockchain technology is used as a tool for authentication, accreditation and certification of student outcomes (architecture).
Goal #5 – Equality and social exclusion		
5.1 5.a 5.b	Financial inclusion for refugee women (Thylin & Duarte, 2019)	It seeks to economically empower refugee women by minimising their degree of vulnerability. They can apply for money through the shops registered in the project, to be able to identify themselves using biometric scanners (architecture).
5.1 5.b	Women's coin (Kamath, 2018)	The aim is to attract donors so that they can invest in initiatives that give women a voice and programmes that promote gender equality through education (cryptocurrency).
5.1 5.a 5.b	Enabling girls and women to save money safely (Blakstad et al., 2018)	Method to save money that is focused on women and girls in sub-Saharan Africa, the infrastructure is based on the Blockchain network Stellar (architecture).
Goal #6 – Clean Water and Sanitation		
6.4 6.b	Automatic water management in irrigation communities (Bordel et al., 2019)	A method of autonomous water control for communities that depend on agriculture and must share a water source or quota (architecture).
6.1 6.4 6.b	The Water Project (Darilek, 2020).	Receipt of donations using cryptocurrencies, which reduces transaction costs and improves auditability. (Service).
6.1 6.4 6.b	Cleanwatercoin (Saleh et al., 2019).	Token that allows users to make an automatic donation of 0.1% for each transaction to fund projects that provide water to vulnerable communities (Cryptocurrency).
Goal #7 – Affordable and Clean Energy		
7.2	Brooklyn Microgrid (Orsini et al., 2018)	It records transactions of energy generated in a community in a blockchain network, providing neighbors with more options to choose their energy sources (service).
7.2	SolarCoin (Johnson et al., 2015), NRGcoin (Mihaylov et al., 2014)	Cryptocurrencies that act as a reward for small solar energy producers, in addition to being tradable, these promote the production of solar energy in a verifiable way. (Cryptocurrency).
7.1 7.2	KWHCoin (Johanning & Bruckner, 2019)	Allows members of a community to purchase renewable energy from a local generation source (Cryptocurrency).
Goal #8 – Decent Work and Economic Growth		
8.7	Slavefreetrade (Kamath, 2018)	Service that allows consumers to track, monitor and evaluate the human supply chain of products registered in the network to confirm that they are obtained without exploitative labour or slavery practices (service).
8.2 8.3	Financial inclusion for local entrepreneurs (Barrutia et al., 2019)	It proposes the implementation of micro-credits to small and medium local entrepreneurs dedicated to tourism through cryptocurrencies and a network of

8.9		payments in the same money (model and cryptocurrencies)
8.2 8.7 8.8	Everledger (Francisco & Swanson, 2018)	This service enables the tracking of diamonds through a blockchain, allowing consumers to be assured that the jewellery is authentic and has been extracted from regions free of conflict and forced labour (service).
8.8 8.10	Etherisc (Kim & Laskowski, 2018).	It offers decentralized, automatically disbursable insurance that is aimed at helping farmers in developing countries (service).
Goal #9 – Industry, Innovation and Infrastructure		
9.3	KWHCoin (Johanning & Bruckner, 2019)	Allows citizens to purchase renewable energy from local generation sources, promoting local investment, and allows small industries and other businesses to access the market (Criptocurrency).
9.3	Micro loans from developed countries (Ammous, 2015)	Proposes that citizens of developed countries make small loans to businessmen and entrepreneurs in developing countries, using cryptocurrencies (model and cryptocurrencies).
9.3	Financial inclusion (Barrutia et al., 2019)	Microfinance model through cryptocurrencies to promote the economic development of small and medium-sized entrepreneurs (model and cryptocurrencies).
Goal #10 – Inequality		
10.c	Bitpesa (Ammous, 2015)	It allows to receive remittances through cryptocurrencies and pays its equivalent in local currency, achieving fast and low cost money transfers and overcoming the little presence of banks in the areas where they operate (cryptocurrency).
10.7	Digital residence system (Scott et al., 2017)	To provide migrants and refugees with an emergency digital identification based on blockchain, thus promoting an orderly mobility policy that fights to protect the rights of these vulnerable groups (service).
10.2	Cryptocurrency for Citizen Philanthropy and Social Entrepreneurship (Jain & Simha, 2018)	Adapts blockchain in the area of donations and social entrepreneurship, allowing donors to have better control over how their money is used and facilitating the matching with organisations that develop programmes that match citizens' aid intentions (model).
10.2 10.c	Bitso (Zbinden & Kondova, 2019)	Promotes financial inclusion through e-commerce, offering lower costs per transaction. People without bank accounts or credit cards can participate (cryptocurrency).
10.2 10.3	Economic passport BanQu (Kshetri, 2020)	This platform is fed by different data sources and allows the most vulnerable people to obtain a digital identity, with which a series of data can be linked, such as financial history, income from remittances, among others. The aim is for this history to serve as proof of access to health and financial services (service).
Goal #11 – Sustainable Cities and Communities		
11.5	Etherisc (Kim & Laskowski, 2018).	Allows small producers to reduce their losses in the event of natural disasters, with cheap and reliable insurance (service).
11.1	Brooklyn Microgrid (Orsini et al., 2018)	Records locally generated electricity in a Blockchain network, enabling citizens to have access to cheap and sustainable basic energy (service).
11.1 11.2 11.3	FairBike (O'Hara, 2018).	Platform for bicycle lending based on Ethereum. Citizens have access to a useful, efficient and environmentally friendly means of transportation (service).
Goal #12 – Responsible Consumption and Production		
12.3	Supply chain (Unicef, 2018)	Solution that ensures control of the food supply chain through blockchain, reducing rates of expired food during distribution (architecture).
12.6	Tracking the origin of meat products (Kim & Laskowski, 2018)	Solution that allows citizens to monitor the origin of meat products, ensuring their quality and promoting sustainable practices (architecture).
12.3	Provenance (Kim & Laskowski, 2018).	Platform that allows companies to communicate to consumers the origin and impact of their products, also providing information on the production and supply chain (Service).
Goal #13 – Climate Action		
13.3 13.b	Regen Network (Howson, 2019)	Facilitates citizens to sponsor regenerative land use practices through Blockchain (service).
13.3	Carbon credits trading (Howson, 2020b).	Service that allows citizens to purchase tokens representing carbon credits to offset the carbon emissions needed to produce a good or service (service and cryptocurrency).
13.3	Saving the planet with every purchase (Howson, 2019).	Start-up that has developed a platform that allows financing the environmental cost necessary to produce a good or service (Service).
Goal #14 – Life Below Water		
14.4 14.b	Fishcoin (Howson, 2020a)	Project that seeks to incentivize data recording by small-scale fishermen in the Global South by offering tokens redeemable for credit as an incentive to share data on a blockchain network, this allows regulators to have better criteria to make decisions (cryptocurrency).
14.2	Cryptocorals (Fraga-Lamas & M. Fernández-Caramés, 2020).	Platform that seeks to protect coral reefs, through the purchase of a virtual coral, people can finance projects that are implemented through a partner NGO (cryptocurrency).

Goal #15 – Life on Land		
15.1 15.3	Regen Network (Howson, 2019)	The platform makes it easier for citizens and companies responsible for climate change to sponsor regenerative land use practices through Blockchain, an initiative that seeks to restore ecosystems (service).
15.6	Registry of genetic markers (Kim & Laskowski, 2018)	Model proposing Blockchain as a means of distributing a library of livestock genetic material (model).
15.1 15.2 15.3	Sustainable wood sourcing (Figorilli et al., 2018)	racking timber areas and forests with the objective of transparently tracking the origin of timber and the use of ethical practices and sustainable forest management (model).
Goal #16 – Peace and Justice Strong Institutions		
16.4	Intelligence and investigation units (Leite & Albuquerque, 2020)	This solution enables the auditability, authenticity, security, availability, integrity verification and confidentiality of files used in the field of anti-crime intelligence and investigation units by means blockchain structures (model).
16.4	Data verification for surveillance cameras (Khan et al., 2020)	Guarantee through a reliable mechanism based on blockchain the authenticity of data generated by surveillance cameras that could be presented as evidence in a court of law in case of a crime (model).
16.2 16.3 16.9	Digital Identity System (Kamath, 2018; Haddouti & Ech-Cherif El Kettani, 2019)	Through a blockchain network, a person can store and manage personal data securely such as birth registration, vaccination record, voter registration, refugee registration, national ID card and other metadata. This data allows them access to public services (service).
16.9	Digital Identity System (Kshetri, 2017b)	Allows the creation of digital identities based on biometric data such as facial and voice recognition through a smartphone, does not require any previous identity document or an email (service).
16.1 16.2 16.9	Preventing human trafficking (Lapointe & Fishbane, 2019)	This solution aims to prevent human trafficking, with a special focus on undocumented children. The network produced a report entitled "Making Invisible Children Invincible", presenting the solution implemented (service).
16.9	Digital residence system (Scott et al., 2017)	Provide migrants and refugees with an emergency digital identification based on blockchain, facilitating an identity registration that reduces the degree of vulnerability of these groups (service).
16.4 16.a	Firearms registration control (Heston, 2017; Soni and Mahler, 2020)	Registration, control and distribution of firearms based on blockchain structures. The objective is to promote the improvement of policies related to the use and possession of firearms and to gradually reduce interpersonal violence and suicides (model).
Goal #17 – Partnerships to achieve the Goal		
17.6	Pilot Blockchain Initiatives for Humanitarian Action (Thylin & Duarte, 2019)	Event to explore and disseminate decentralized Blockchain-based solutions to protect the rights of women and girls in humanitarian environments (service).

3.1.B Findings

The main findings of the proposed solutions can be summarized as follows:

The main benefits of blockchain technology for delivery of services are due to its use as a means of exchanging economic assets through an underlying cryptocurrency. In addition, its characteristics allow it to go beyond and to propose innovations in other areas of social impact, such as identity data processing, optimisation of supply chains, property rights and gender equality, among others. These innovations are based in the ability of this technology to effective management of information in a secure and accepted by all participants way.

3. Resource-management approach

Below, some representative solutions of the potential of blockchain technology to address the challenges of SDGs are described.

3.1. Solutions

In this subsection, the different solutions are described to better explain the added value provided by blockchain ecosystems.

Goal #1 – No Poverty

To help in achieving this goal, blockchain-based direct fundraising projects by nonprofit organizations have been implemented to reduce the effects of poverty (BitGive, 2019). The idea consists in a platform based on blockchain which helps to manage the use and purpose of these funds. This provides greater confidence for philanthropic organisations to engage in collaborative efforts and continue to make larger and larger donations, without the risk of fraud (Benefactory, 2020). It provides an infrastructure able of registering and retrieving any digital token (such as cryptocurrencies) anywhere in the world. This represents an opportunity to diversify and capture other sources of finance to help eradicate poverty (WeiFund, 2021).

Goal #2 – Zero Hunger

To reduce hunger, blockchain research focused on agricultural production. For this, land registries, financial inclusion, sustainable production, and consumption are necessary. This actions have direct and indirect effects to increase production and to reduce hunger. Above issues can be aborded by blockchain as follows: first, registering property on blockchain reduces notary service costs

(BenBen, 2021); second, access to financial resources can increase agricultural production, and consequently the incomes of small farmers; and third, certification schemes favour resilient agricultural practices, establish free access to information and trade balance in the supply chain (Bext360, 2019).

Goal #3 – Good Health and Well-being

In this area, blockchain can be used to aid the management of the pharmaceutical resources and monitor the commercialization process of pharmaceutical industry. There are proposals based on smart contracts to register transactions and movements of medicines to prevent counterfeiting of products. In this case, the immutability of blockchain cancel the asymmetry of information between manufacturers and marketers (Uddin, 2021).

Goal #4 – Quality Education

In this area, the blockchain research is twofold: grant management and sharing of educational resources between universities. An adequate control improves collaborative performance and benefits the exchange of resources, both financial and educational (Bálint et al., 2019; Rashid et al., 2019). Smart contracts are used to query grades from an external repository. If the qualification requirements are met, the system transfers cryptocurrencies to the student's wallet. In this way, scholarships, grants or loans are stored in smart contracts and an immutable commitment is created between students and sponsors of university education.

Goal #5 – Equality and social exclusion

Blockchain management services help to reduce the gap of social and gender inequality because they are able to channel financial resources toward social programmes and provide equal opportunities without distinction (Mora et al., 2021a; Mora et al., 2021b). In this line, blockchain research focuses on financial inclusion for vulnerable populations or free access to educational material, among others examples (GiveTrack, 2019).

Goal #6 – Clean Water scarcity and sanitation

Research on blockchain exhibits three cases of usage related to water management: monitoring and distribution, quality control, and trading. With these requirements, solutions and benefits are identified to improve the lifestyle in urban and rural areas.

In many areas where water is very scarce, an adequate irrigation schedule is required to maximize agricultural production and minimize water consumption. The use of blockchain solutions provides security and trust to the system for user interaction, monitoring the use of this resource and providing traceability of its decentralized consumption to water supply chain management (Munir et al., 2019; Maouriyan et al., 2019; Mahmoud et al., 2019). Likewise, there are solutions that establish irrigation rules and controls according to a share of water allocation managed by smart contracts (Bordel et al.,2019).

In short, the transparency and immutability of water and sanitation facility management are reliably ensured by this technology, which combined with other Internet of Things (IoT) paradigms, provide consumer confidence and establish transparent processes for setting fair water prices.

Goal #7 – Affordable, reliable, sustainable energy

Blockchain research provides energy-efficient management solutions primarily related to how to market surplus generation amongst consumers in community collaboration scenarios. The solutions and benefits obtained to improve access to clean renewable energy are described below.

Some households have started generating energy using solar thermal collector and photovoltaic cells. The amount of energy produced depends on climate factors. When there are surpluses, the possibility arises to open a direct market for marketing between two types of stakeholders: prosumers (who have surplus energy for sale), and consumers (who need to buy energy). Currently, energy demand and supply management are controlled by a central authority. These entities have played an important role in overseeing energy marketing. However, centralization suffers from some disadvantages, such as: lack of privacy, single point of failure, and server attacks. To solve this problem, (Lee et al., 2019) uses blockchain technology to set up a P2P energy trading system between neighbors. When a negotiation is achieved, a smart contract performs the pairing between prosumer and consumer to execute the payment process.

From these proposals, the management of energy generation and demand in a community, for example, a city, can be undertaken by microgrids spanning a region, city area or the entire city. When domestic demand is not met, the microgrid has the ability to buy power from the utility grid (Afzal et al., 2020). All generated data flow is stored on a community blockchain. In addition, the definition of prices and execution of financial transactions uses procedures based on smart contracts (Khalid et al., 2020) that allow the recording of consumer and prosumer data, P2P local market transactions, and trade transactions between the prosumer and the main grid. This type of solution minimizes dependence on main grids and makes it possible to exchange energy based on the minimum physical distance between pairs, minimizing: possible transmission losses (online) and power demand from the main grid during peak hours. These actions help not to overload the operation of a central plant, while encouraging the use of renewable energy for community production and consumption.

The monitoring and correctness of operation of the scheme depends on three types of nodes. Firstly, a blockchain node-based public key infrastructure for service certification and authentication. Secondly, even nodes to validate transactions and generate the correct sequence of blocks. Thirdly, request nodes that manage the transactions between the prosumer and the consumer (Noor et al., 2018). With this organization, there are

wallet-based solutions configured and linked to specific "power coins" cryptocurrency addresses. In this scenario, a prosumer launches an offer of a certain amount of energy for a number of power coins. A consumer can accept the offer and begin a negotiation process. If an agreement is reached through a bid, smart contracts enable the transfer of energy and power coins between participants. This procedure provides liquidity within the scheme and energy inclusion of the inhabitants of a community.

There are other initiatives that connect consumers through an electricity pool based on smart contracts and under the same principle (SunContract, 2017).

Goal #8 – Decent Work and Economic Growth

Blockchain could provide a new transparent way of recruiting and managing human resources without the need for intermediaries. By means of smart contracts the employment commitment of the parties can be encrypted, signed and automatically registered in the blockchain. In this context, payments are executed instantly, once the job is completed. This method guarantees equality in the job conditions anywhere in the world and allow third countries to access to job opportunities whenever found (Chrono.tech, 2021).

Goal #9 – Industries, innovation and infrastructures

Technology management capabilities of blockchain have been harnessed to propose solutions to help industries to improve their production process. There are many proposals for logistics (Cao et al., 2020; Wang et al., 2020; Agrawal et al., 2021) and infrastructures management (Turk and Klinc, 2017). In addition to blockchain structures, smart contracts are implemented to address logistical issues about the operation time of each process in relation to the planned schedule. In this way, the timeliness of precast delivery is improved, and bottlenecks are identified in a timely manner.

It is especially important the advantages of blockchain traceability to the food industry (Ripe.io, 2015). In this way, food quality is tracked from the farm to the final consumer. It connects food suppliers (restaurants, supermarkets, farms) with local community members and provides up-to-date information about schedules, transport routes, prices and product availability. Is also helps to avoid the price hike from the farmer to the final consumer.

Goal #10 – Inequality

Inequality is really a big challenge for vulnerable people who have difficulties in trying to move forward in their life-conditions. The management of aids becomes a challenge because the tools used to offer humanitarian assistance are useless when this people decide to move to another region or country as migrants. The ID systems based on this technology could easily provide an unequivocal and personal identity (Argento et al., 2021) to the people on the receiving end of humanitarian aid and other social services, regardless of the country in which they are located (Mora el al, 2021a).

Goal #11 - Sustainable transport

Research on blockchain exhibits two cases of transport-related uses in cities: P2P vehicle sharing, and real-time road traffic information.

Smart transportation optimizes existing mobility resources, rather than creating new ones. An efficient mobility alternative promotes ride-sharing, i.e., the use of the same vehicle to transport multiple people who share common routes to reach a destination. Thus, profitability is maximized because expenses are amortized through the use of empty seats. In addition, traffic and environmental pollution are reduced because there are fewer vehicles driving along the same route. Based on this approach, the blockchain-based smart transportation system supports shared travel with the possibility of a passenger changing vehicles when taking another route (La' Zooz, 2017). Drivers and passengers share their location and travel routes through an App. The transmitted data is verified in real time and recorded on a blockchain. The system generates cryptocurrency tokens and gives back to users who share their location (DOVU, 2018).

A smart transportation system essentially requires a journey planner. A user needs to know alternatives for travel routes between various transport providers and methods of acquisition, payment, and confirmation of e-tickets. Mobility services are currently centralized and play an important role in managing transportation supply-demand. However, they face trust and scalability issues when managing connections between multiple providers because of the heterogeneity of the schemes they own. Through a blockchain structure you can create a collaborative environment between carriers and travelers (Nguyen et al., 2019). Basically, a traveler requests information about a travel route. Then smart contracts (which include information about possible routes and means of transport) are sent to the network. The traveler selects and pays the travel option according to their preference (route, comfort and price). Then, a smart contract becomes a ticket validated and confirmed by all suppliers, prior to registration within the blockchain.

One aspect that affects mobility is vehicle congestion in cities. To address this problem, a traffic light mechanism based on the consortium blockchain and vehicular ad-hoc network (VANET) can improve mobility in cities (Zhang et al., 2019). In this scenario, a vehicle sends the traffic status of the road along which it is driving. The information is then sent to the blockchain for validation and subsequent registration. Using artificial intelligence and parallelism algorithms, smart contracts are activated for dynamic traffic light regulation.

Goal #12 - Waste Management

Blockchain-based solutions to address this challenge are geared towards raising awareness and providing incentives to recycle waste, and towards waste management.

In relation to the first usage case, there are solutions that promote the identification of georeferenced pollution sources and aim to involve citizens to raise awareness of plastic footprint (Lynch, 2018). Citizens can identify and report points with plastic garbage to a public website (OpenLitterMap.com). The information received is processed and categorized into a blockchain-like structure. A wallet is also created to incentivize and reward the user for their information by paying with a virtual currency (LitterCoin).

Along this same line, there are other architectures to promote adequate ecological behavior (Recereum, 2017; Franco et al., 2019). This system motivates citizens in an urban waste collection activity (plastics, paper, aluminum, textiles and batteries) in exchange for a cryptocurrency (GreenCoin). With these cryptocurrencies, the user can exchange them for goods and services in partner businesses.

Other solutions focus on the traceability of certain types of waste based on their life cycle (Dua et al., 2020). In the first stage, the manufacturer records the characteristics of the product. Each transfer of ownership is then recorded from its creation date to the end of its useful life. A transfer rate is calculated to achieve sustainability of the project. The value of this tax is paid proportionately to each of the former owners of the electronic device. To do this, when the life of the device ends, it must be delivered to a recycling center. With this strategy, participants are motivated to deliver the product to authorized recycling centers.

Another important consideration in waste management is waste prevention and reuse. This activity is a lucrative business that needs transparency and auditing in order to avoid bad practices related to disposal, transport and recycling. To address this management problem, blockchain-based solutions and smart contracts can provide the traceability needed for waste management (Schmelz et al., 2019). The following information is recorded: stakeholders, waste management facilities, waste classification and volume, activity log and timestamp. Thus, the audit process obtains reports of different types that allows alerts to be issued about any irregularities that have been detected.

The lack of waste treatment infrastructure in rural areas of developing countries also has negative effects on health and causes irreversible damage to the ecosystem. In this environment, farmers have no choice but to incinerate crop waste, wood and other agricultural waste. In the face of this problem, there are solutions to the trade in biomass energy and blockchain-based agricultural products (Zhang, 2019). The scheme defines two stakeholders: waste recycling companies and farmers. Farmers sell their waste to a company in exchange for three options: (a) cryptocurrencies, (b) food consumption coupons such as fertilizers or raw materials, and (c) energy supply coupons on their farms. All previous transactions are recorded on a blockchain and the exchange is executed through smart contracts. Thus, these wastes are converted by companies into clean energy, and farmers have the opportunity to stock up on: food, supplies and energy. In addition, it represents an opportunity for collaborative work between the community and the companies that seek to preserve the environment.

Goal #13 - Climate action

Blockchain technology in this field is primarily aimed at providing solutions in the trading licence system, toxic gas leakage detection, and air quality monitoring system.

In relation to the first problem, a blockchain-based P2P trading system is proposed to exchange an energy and carbon credit certificate by providing transparency and market confidence (Hua et. al, 2020).

In relation to emissions monitoring, the combination of blockchain registration systems with IoT (Internet of Things) measurement technologies establishes homogeneous measurement criteria and provides reliability to the data provided (Mishra et al., 2020). These solutions minimize registration errors and eliminate fraud arising from the accounting and measurement of gas emissions.

Finally, the third usage case is based on the same principle of immutable registration of real-time air pollution data (Niya et al., 2018; Han et al., 2019; Benedict et al., 2019). The information is then encrypted and retrieved by users for analysis. Thus, the system provides alerts on pollution levels to environmental monitors.

There are proposals to publish the data on the Distributed Web using the InterPlanetary File System (IFPS) (De Tazoult et al., 2019) and to register the IPFS hashes on a blockchain to ensure its immutability.

Goal #14 – Life below water

In this area, there are proposals for a marine blockchain for the transparent, reliable and accessible registration of oceanic phenomena. This system helps to improve the collaboration among multiple parties involved in the safe sharing of marine data. It allows better responsiveness, reduce service delivery errors and increase data reliability (Fang et al., 2020).

Regarding the exploitation of fisheries resources, the registration of the fishing operations in a blockchain can also be used for managing the supply chain and analyzing the conservation of the marine ecosystem through traceability of fishing operations (Cook, 2018; Tsolakis et al., 2020). These proposals aim to avoid illegal fishing and unethical practices in the fishing industry. The platform can also model business processes, tracks assets and builds a transparent supply chain. As a result, the transparency and traceability provided enables sustainability of the marine ecosystem, improved trade, quality assurance and supply chain efficiency.

Goal #15 – Life and Land

For this purpose, blockchain technology can be used to preserve nature and the virgin land in developing countries. The proposal consists in a common transparency platform for registering the land use and the property rights. Through immutability of blockchain,

these platforms provide a reliable tool for recording data of timber production and transportation, which helps to assess environmental impact, manage of wood production and combat illegal deforestation (GainForest, 2021; Villares, 2021).

In this same line, other architectures based on blockchain and microservices to manage forest logging have been proposed (Figorilli et al., 2018; Cueva-Sanchez et al., 2020). This solution makes forest management plans transparent, as well as the traceability of the logging process carried out in the forest. In this way, the rate of fraud and illegality related to the registration of trees and forestry operation certificates is reduced.

These platforms based on blockchain can also be used as payment platform for commercialization and exchange of fisheries and agricultural products in a secure and reliable way between producers and consumers.

Goal #16 – Peace and Justice Strong Institutions

The advantages of blockchain are very important to make strong institutions for the citizens. Currently, there are ongoing initiatives aiming to increase the financial transparency to the institutions by means of the traceability of operations provided by a blockchain open distributed ledger. Through this system, citizens could consult the destinations of the public founds and reinforce trust in institutions (Mora et al., 2020). This is significatively important in these cases where the citizens voluntarily contribute with donations, such as NGOs.

Other important contribution to make stronger institutions is the role in the management of the democracy itself. There are many proposals and small-scale experiments for implementing e-voting systems based on blockchain which will imply an extraordinary change in the way citizens participate in decision of public institutions (Barański et al., 2020; Rathee and Saini, 2021).

Goal #17 – Partnerships for the goals

To advance in this objective there are also proposals for strengthen the means of implementation of Goals. For example, a governance framework based on blockchain. This proposal defines the guidelines for management the information transmission and sharing knowledge competence between industry and government (Zhang et al., 2019). By means this kind of collaborations, the information can be easily shared among stakeholders to know where the priorities are and to define common strategies to address them.

Table 2 schematically shows the main contributions for resource management.

3.2.B Findings

The main findings of the proposed solutions can be summarized as follows:

The capacity of this technology to address the challenges of resource management is very important and it is proving useful in many cases. The main used feature is the ability to provide immutability and traceability to the data registered in the blockchain. This capacity gives trust to the users and citizens in the veracity of the information produced from it and allows the creation of decentralized management systems where all users can cooperate. The immutability of information is combined with smart contracts and cryptocurrencies to produce new kinds of business and new forms of transactions which allow incentive citizens and other users to collaborate with the achievement of the objectives.

Table 2
Solution proposals for SDGs based on blockchain technology, from the resource management point of view.

SDG GOAL/Target - Initiative		Novelty (type of solution)
Goal #1 – No Poverty		
1.1	Cryptocurrencies donation platform (BitGive, 2019;WeiFund, 2019)	Founds registration by smart contracts prevent the misuse of funds (cryptocurrency, platform).
1.1	Ethereum platform to recruit volunteers and donors.	Smart contracts provide the rules for defining charitable groups and donations to social projects (cryptocurrency, platform).
Goal #2 – Zero Hunger		
2.2 2.3	Blockchain-based platform for land management (BenBen, 2021).	Blockchain platform which facilitates transactions related to the purchase, sale and lease of land (platform)
2.4 2.B	Blockchain-based platform for coffee traceability (Bext360, 2019)	Blockchain platform records weight and quality of the food products. According to these variables, the farmer receives the payment in his wallet (platform).
Goal #3 – Good Health and Well-being		
3.5	Blockchain Medledger (Uddin, 2021)	System to enable a secure and efficient drug supply chain transactions and provide a reliable traceability solution for consumers and intermediaries (architecture).
Goal #4 – Quality Education		
4	Digital learning chain structure (Bálint et al., 2019; Rashid et al., 2019)	Platform for managing student grants (cryptocurrency, platform).
4	University Education Resource Sharing (Meng & Zhang, 2021)	Platform to manage the exchange of educational resources between universities (platform).
Goal #5 – Equality and social exclusion		
5.5	Donation platform (GiveTrack, 2019)	Donation platform (in bitcoins) to contribute to girls' education in Afghanistan

5.A		(platform)
Goal #6 – Clean Water scarcity and sanitation		
6.b	Water monitoring (Munir et al., 2019; Bordel et al., 2019)	Monitoring and scheduling of irrigation, control and allocation of irrigation quotes (architecture).
6.4	Water distribution (Maouriyan et al., 2019).	Traceability and data aggregation mechanism for water distribution system (service)
6.3	Water control quality and management (Shi et al., 2019)	Provides transparency and immutability to the management of water facilities and sanitation (service)
6.5	Water trading (Smart4Tech, 2019; Civic Ledger, 2020)	Water Credits Mechanism based on blockchain (Water Ledger) to design, register and trade water rights (cryptocurrencies)
Goal #7 – Affordable, reliable, sustainable energy		
7.a 7.2	P2P energy trading solution (Lee et al., 2019; Li et al., 2019; Cutsem et al., 2020)	Renewable energy trading systems that remove the need for a central authority since the same participating nodes validate the operation and guarantee the integrity of the transactions by means blockchain, smart contracts and cryptocurrencies (architecture and cryptocurrencies)
7.a 7.2 7.3	Distributed optimization and control (Khalid et al., 2020; Afzal et al., 2020)	Local home energy consumption scheduler. Microgrids are established among community consumers. The management of these grids are made through blockchain and smart contracts (service)
7.a 7.2 7.3	Certification of energy service providers (Noor et al., 2018)	Authentication and certification energy services based on blockchain nodes that manage transactions between users of the system (prosumer and consumer) (architecture and cryptocurrencies)
Goal #8 – Decent Work and Economic Growth		
8.2 8.5	Blockchain Human Resources Solutions (Chrono.tech, 2021)	A system based on blockchain, smart contracts and cryptocurrencies allow transparent and fair recruitment without the need of intermediaries (architecture and cryptocurrencies)
Goal #9 – Industries, innovation and infrastructures		
9.1	Logistics management (Cao et al., 2020; Wang et al., 2020; Agrawal et al., 2021)	Blockchain-based framework for improving supply chain traceability and information sharing (framework)
9.1	Infrastructures management (Turk and Klinc, 2017)	Blockchain systems provide solutions to many current problems in construction information management (architectures)
9.1	Food industry traceability (Ripe.io, 2015)	A blockchain system allows register and trace food quality information from the farm to the final consumer (architecture).
Goal #10 – Inequality		
10.2 10.7	Legal identity management systems (Mora el al, 2020; Argento et al., 2021)	ID systems supported by blockchain technology provide a tool for people identification in an accessible and unalterable way with which to manage humanitarian services for vulnerable people, such as migrants (architecture).
Goal #11 – Sustainable transport		
11.2	P2P vehicle sharing (La' Zooz, 2017; DOVU, 2018; Arcade City Inc, 2020).	System for travel sharing. Travel schedules and routes are created in a blockchain according to geographical areas and rate of use of the service. A cryptocurrency is used to remunerate users who share their routes with other passengers. (architecture and cryptocurrencies)
11.2	Journey planner for mobility service (Nguyen et al., 2019).	By means of a blockchain structure and a transaction procedure based on Smart contracts, user preferences are matched with the possibilities of the transport providers (service)
11.2	Real-time road traffic information (Zhang et al., 2019)	Traffic light procedure to manage vehicle traffic based on the information sent by each vehicle in a VANET and stored in a blockchain. (model)
Goal #12 – Waste Management		
12.5	Incentive system for the recycling of urban waste (Recereum, 2017; Lynch, 2018; França et al., 2019)	A system based on blockchain and virtual currencies is proposed to reward the citizens for indicating places of contamination and collaborating in recycling (architecture and cryptocurrencies)
12.5	Traceability of waste (Schmelz et al., 2019; Dua et al., 2020)	A blockchain-based system provides transparency and auditing to prevent bad practices related to waste disposal, transport and recycling. (architecture)
12.4	Waste management (Zhang, 2019)	Waste generating agents can trade with it with the aim of it being used to generate energy (biomass) using blockchain infrastructure and payment with cryptosystems. (architecture and cryptocurrencies)
Goal #13 – Climate action		
13.2	Trading licence system (Hua et al., 2020)	P2P trading system for Carbon Credits in which transactions are recorded on a blockchain (service)
13.2	Toxic gas leakage detection (Mishra et al., 2020)	Quantification, classification and detection of gas contamination in real time. The measurements are stored in a blockchain (architecture)
13.2	Air quality monitoring system (Han et al., 2019; Niya et al., 2018; Benedict et al., 2019; De Tazoult et al., 2019)	Monitoring and storage of air pollution indicators in real time. The measurements are stored in a blockchain (architecture)

Goal #14 – Life below water		
14.1 14.2	Blockchain for Marine Data Management System (Fang et al., 2020)	A blockchain-based system is used to protect and share marine network data information (architecture).
14.4 14.B	Fisheries supply chain (Cook, 2018; Tsolakis et al., 2020)	Supply chain management for analysing the conservation of the marine ecosystem through traceability of fishing operations (architecture)
Goal #15 – Life and Land		
15.1 15.2 15.3	Blockchain for Land Management and Conservation (GainForest, 2021; Villares, 2021)	A blockchain-based platform allows registering the land use, timber production, transportation data and the property rights. (architecture).
15.4 15.5	Wood supply chain (Figorilli et al., 2018; Cueva-Sanchez et al., 2020)	Architecture to manage forest management plans as well as the traceability of the logging process (architecture)
Goal #16 – Peace and Justice Strong Institutions		
16.5 16.6	Support Models Based on Cryptocurrencies (Mora et al., 2021a; Mora et al., 2021b)	A distributed ledger technology based on blockchain allows audit and trace financial operations of public funds. Citizens can check where their money is going (framework).
16.7	e-voting systems (Barański et al., 2020; Rathee and Saini, 2021)	Electronic voting system based on blockchain will provide citizens a hight participation in democratic processes (architecture).
Goal #17 – Partnerships for the goals		
17.14 17.16 17.17	Governance framework (Zhang et al., 2019)	Knowledge Governance Framework in Dynamic Alliance based on blockchain for managing smart services and sharing knowledge competence between industry and government (framework)

4. Blockchain for city management

In this section we discuss potential and already deployed solutions based on blockchain for management of different areas of the city and their government. Most of the described proposals in this area contribute to progress on governance and e-government (Guarda et al., 2021; Grover, 2021) and provide a response to how advance in the challenge of sustainability of urban spaces (Bibri, and Krogstie, 2017). This governance may be applicable to other government scales, such as regional or country government.

Citizen transactions typically suffer from a huge trust deficit. In most cases they also require costly monitoring, reputation checks or third-party intermediation which are costly and time-consuming (Allessie et al., 2019). The introduction of blockchain in the government has resulted to be a catalyst for tackling most of these issues. In the case of smart city, the blockchain-based solutions provide a common platform to connect other services of the city and enhance their benefits. Other technologies have also played a key role in this progress. In this set, mobile computing, Internet of Thigs (IoT), and Cloud computing are highlighted. Other important technologies are big-data, IA, or 5G among others.

In this context, mobile computing mainly refers to the potential of smart devices and other wearables in the hands of the citizens, which have become ubiquitous in modern days. Trough new Apps and mobile services, city-administrators can provide new citizen-centric tools to facilitate the relation of the user with the city and the access to the services (Allam, 2021; Ji et al., 2021). In addition, mobile devices are the common way to access to most of the services supported by blockchain technologies.

IoT is a new paradigm able to provide sensing, computing and communicating features to devices. These devices or "*things*" are used to acquire data from the city environment and provide valuable information to city administrators to make decisions (Mora et al., 2019b; Hemanth et al., 2021). A smart city collects and processes privacy-sensitive information from people's lives and environments, and thus, security and privacy issues become a critical issue (Zhang et al., 2017). To this end, the combination of IoT and blockchain increases security in accessing to the data acquired by the things and in accessing to the control of devices (Nguyen et al., 2020).

Cloud Computing paradigm is one of the most innovative strategies in terms of the adoption of information technologies by society. This model offers ubiquity and computation power to city-services (Mora et al., 2016). The cloud has become to the place where send the data for further processing and where host the services of the city. In this scenario, blockchain provides trust to validate user data integrity and provide easy data access (Cha et al., 2021).

The concept of e-government is related to role of public administration narrowed to the digitalization of the resources and formalization of the procedures (Allessie et al., 2019). The new paradigm of the Digital Government (DG) refers to the usage of ICT technologies to embrace good government principles and achieve policy goals.

E-government is a powerful tool to implement global sustainability goals and addressing the previous challenges. Most of the solutions are deployed in smart city environments where the advantages they provide are combined with other functionalities of the digital society to advance in the achievement of SDGs and improve the quality of life of citizens. In this field, the main and most representative solutions are described below involving several areas of the city management. In many cases, these proposals can be combined with other digital services provided by the city to create synergies with them and reach a larger number of people. Table 3 compiles summarizes the main novelties of the proposals.

#1 Citizen - public administration relation and registry services

Usage of blockchain to deploy formalized, digital administration models aim at improving the quality of interaction between citizens and the administration by a change of bureaucratic administration into smart country management-oriented on citizens. This goal is planned to be achieved by especially by increasing the citizens' trust factor that is ensured by the opensource code and cryptography that increases the information protection level as well as allows to control access rights.

The other factor is the optimization of the interaction and processing of administrative cases by formalization in the form of active scripts realized on each level of the case that eliminates errors during collecting the documents, tracking their consistency, and ability to process them without the requirement of intermediaries (eg. administrative officers or layers). Also, the procedures in the form of smart contracts are enforced by law as they are constructed and controlled by a legal entity. From the perspective of the government amortization of the process allows to introduce control procedures reducing the potential for corruption and abuse as well as reduces the cost and the complexity of the IT infrastructure.

In this context of public services, increased speed and efficiency is another key feature provided by this technology (Datta, 2021). One of the examples of the processes optimized with the blockchain technology in public administration has been shown in (Mora et al., 2019a). In the paper, the authors show usage of blockchain for protection of the urban legality or regime of urban infractions, which is repressive against the commission of an urban wrongful act that does not conform to the regulation or planning. The proposed model also allows the controlling process of obtaining licenses for the specific case of urban planning. The benefits of the deployed model reduce the operating time, simplifies understanding of the whole procedure by the citizens and gives the legislative control for the administrative. In this same line, registration services based on blockchain are proposed to automatically public register assets and improve the sometimes costly and slow traditional process (Krishnapriya and Greeshma, 2020). This is specially recommended for assets witch need including extra security and having a real-time access to data. For example, in the case of firearms control (Heston, 2017; Soni and Mahler, 2020).

Moreover, the personal data collected by smart IoT devices interconnected and public institutions with the aim of providing services need also to be protected. To face this issue, blockchain enables powerful and elegant solutions which are able to provide mutual trust between individuals and governments, leading to a greater transparency of activity and less operational overhead (Theodorou and Sklavos, 2019; Yang et al., 2019). In addition, new blockchain-based approaches led in a more secure authentication and authorization process for smart city applications and data manipulation (Brandão et al., 2018; Khan et al., 2018; Esposito et al., 2021).

#2 Digital Identity (DI)

Digital identity is a particular use of a registration service, but in this case, it is related to citizens. This service has been reported previously to address some identification issues of migrants and refugees due to they don't have any identification document (Kshetri, 2017; Haddouti & Ech-Cherif El Kettani, 2019; Lapointe & Fishbane, 2019).

In a smart-city environment, identity services allow the providers and city-administrators to know information of interest from the citizens that uses their services, for example: address, phone number, credit card numbers, among others, and also anonymity if needed. Some of these data are very sensitive information, and therefore need a secured data-structure from being exchanged or used to make transactions (Rivera et al., 2017). Blockchain ensures its integrity as well as provides control on access to this information. Based on stored in the blockchain ledger of changes records digital government can introduce services that provide personal identity system that offers authentication and digital signature functions to the citizens (Hou, 2017). The adoption of digital identity solutions helps to empower citizens and build a more connected digital society (Argento et al., 2021; Sinha and Pradhan, 2021). Moreover, blockchain used as a basis for government digital services is also very useful as document management system. Due to its immutability and transparency is provides security that involves trust not found in usage of other technologies that allows to implement reliable recording (Lemieux, 2017) of changes and time stamping (Kolydas, 2019) that directly allows to trace back decisions taken in a given cases (Ølnes et al., 2017).

This DI don't need any physical document or card since it can be deployed and invoked as a service (Lee, 2017). It can be consumed from a mobile device to reduce on-site infrastructure and facilitate the access to the city-services.

#3 Democracy and civic participation

One of the most promising application of the blockchain technology in digital government services is promoting participatory initiatives (Benítez-Martínez et al., 2021). Achieving greater participation in public affairs of citizens results definitely in a better democracy and in the strengthening of democratic institutions. This approach is to increase reliability of the elections using the open ledger as well as provide common tool to perform voting available for all citizens in the society. Some countries have already initial developments behind, as an example can be served Switzerland and Russia (Germann & Serdült, 2017, Gaudry & Golovnev, 2020). Using for storing the votes immutable records this approach guarantee that they are can not be changed. Also, blockchain gives the opportunity for the voters to control over the counting the votes (Rathee and Saini, 2021). Solving the problem of adding a specific vote and separating it from the voter e.g with blind signatures

(Barański al., 2020) gave the full possibility of use of blockchain as a reliable technology to conduct elections.

#4 Digitizing currency and payments

The new distributed ledger techniques based on blockchain can reduce the infrastructure cost of financial services of the municipality. There are several ways to achieve these advantages.

In first place, the government could canalize payments through a decentralized blockchain structure to register them and provide transparency to the citizens. It helps handle money transactions without use of intermediaries. The citizens can make the payments by means their mobile phones (Ngo, 2021). In addition, blockchain can contribute to the growth of services as people can easily make micropayments for them. For example, pay several cents to go from one subway stop to the next one.

Secondly, in a more general scheme, the blockchain structure can also be used to represent any tradable asset by means 'crypto tokens', for example a ticket of a public transport. This approach allows city government the management of this services without need of money to pay.

Finally, other fiduciary tokens can be created. In this way, the cities can use a form of cryptocurrency to allow certain types of payments with the administration. This is similar to well-known bitcoin cryptocurrency. This virtual currency could be exchanged for city services, such as public transport trips, parking time, and even municipal taxes. In this way, solidarity cryptocurrencies are emerged as community currencies to enhance mechanisms of interaction among individuals and organizations that are not strictly economic (Diniz et al., 2020).

#5 Tax Collection

One of the first areas where blockchain is the perfect tool for application is the domain of taxes (Wijaya et al., 2017; Søgaard, 2021). Blockchain on the one hand, provides the functionality to verify and correction of the data in a certain way. On the other hand, using it, tax authorities would be able to quickly and confidently verify the information sent.

It is easy to imagine a scenario where smart contracts are used to pay taxes. For example, after completed transaction, this procedure would automatically collect the amount due and send it to the tax authorities. This information, together with the time-stamp, would be permanently stored in the blockchain, which would lead to a significant reduction in the number of errors and would be a permanent and invariable proof of payment.

One of the first practical implementations of the tax systems based on blockchain is *VATCoin* (Ainsworth et al., 2016) that is planned to be deployed in all the countries associated with the Gulf Cooperation Council. The condition for application is the adoption of a uniform 5% VAT rate by all countries associated with this organization.

#6 COVID-like management situations

Recent pandemic situation has challenged the management ability of public administrations. New technologies such as blockchain has demonstrated its capacity to deliver innovative tools for making smarter decisions regarding the pandemic, including social distancing and quarantine measures. Blockchain is supporting efforts around the globe to battle the virus (AlMuhairi, 2020). The main features are due its decentralized structure which enables a fast and secure access to health data that allows patients and doctors to detect symptoms in the early stages (Treiblmaier et al., 2020). Digital contact tracing Apps have proliferated for tracking COVID-19 patients and know potential contacts in order to avoid further transmission and reduce hospital overload (Mashamba-Thompson and Crayton, 2020; Idrees et al., 2021). The identity of people can be anonymized in the blockchain to maintain personal information secure and confidential.

In this line, other case use of its potential in handling data transactions securely, is the proposals for vaccine supply management information system. This system uses blockchain technology for assuring the transparent tracing of COVID-19 vaccine registration, storage and delivery. It also allows self-reporting of side effects (Antal et al., 2021).

These examples are related to e-health applications of blockchain, where this technology provides a good solution for the difficult issues of data privacy and information distribution.

Table 3.
Solution proposals based on blockchain technologies from smart city level.

Target - Initiative	Novelty (type of solution)
#1 Citizen - public administration relation	
Management City Model (Mora et al., 2019a)	Perform automatic licensing procedures by means smart contracts and blockchain technology (blockchain & smart contracts).
Security and privacy framework (Yang et al., 2019)	Decentralized framework based upon blockchain and AI to provide a secure and privacy-preserving infrastructure (blockchain).
Authentication and authorization (Esposito et al., 2021)	Solution for distributed management of identity and authorization policies while maintaining a global view of the security policies within the system (blockchain)
Securing Property Registration (Krishnapriya and Greeshma, 2020)	Land Registration System based on Blockchain (blockchain).
#2 Digital Identity	
ID-Service (Argento et al., 2021)	A Blockchain-Based Platform to Support Digital-Identity-Aware Service. (blockchain)

Zero-Chain (Asamoah et al., 2020)	Digital identity solution for all components of the smart city environment (blockchain).
BIDaaS (Lee, 2017)	ID as a service (IDaaS) for digital identity management.
#3 Democracy and civic participation	
I-Voting on Stellar Blockchain (Barański et al., 2020)	Method based on a blind signature used to construct reliable voting protocol. (blockchain)
Neural blockchain (Benítez-Martínez et al., 2021)	A new blockchain concept, which organizes the blocks as a neural system, is combined with the implementation of a virtual token to reward participants (blockchain & cryptocurrencies)
Electronic Voting Application (Rathee and Saini, 2021)	E-voint system based on a smart contract using Ethereum (blockchain & smart contracts)
#4 Digitizing currency and payments	
Blockchain Payment System (Ngo, 2019)	Peer-to-peer (P2P) payments to allow instant mobile payments among users of different banks. (blockchain)
Blockchain Powered Parking Solution for Smart Cities (Jennath et al., 2019)	A non-fungible token system representing unique parking lots is created. These tokens are exchanged through smart contracts over blockchain (blockchain & smart contracts)
Liverpool Local Pound (LLP, 2021)	Cryptocurrency created to keep money circulation inside the city of Liverpool's economy (blockchain & cryptocurrency)
#5 Tax Collection	
VATCoin (Ainsworth et al., 2016)	Cryptocurrency created and used used in tax compliance (blockchain & cryptocurrency)
Blockchain-based value-added tax system (Wijaya et al., 2017)	A new protocol creates a transparent and secure VAT system as well as simplifies the process of administering the VAT (blockchain)
Platform for VAT settlement (Søgaard, 2021)	Platform for value-added tax (VAT) settlement that is enabled by blockchain technology (blockchain)
#6 COVID-like management situations	
Apps for COVID-19 Pandemic Management (Idrees et al., 2021)	Analysis of risks, issues, and challenges associated with the available contact tracing apps based on blockchain technology (blockchain)
Technmology for Self-testing (Mashamba-Thompson and Crayton, 2020)	Combination of blockchain and artificial intelligence tracking system to enable the rapid diffusion of information (blockchain).
Vaccine supply management information system (Antal et al., 2021)	Blockchain platform for COVID-19 vaccine supply management (blockchain).

4.1. Findings

Blockchain technology has led to a fundamental shift in the way city operates. It has triggered a strong impulse to the development of the smart city by facilitating the service-delivery to the citizens, the resource-management and the city administration.

The characteristics of its applicability are the same that in the other cases described in the previous sections (transparency, inmutability, etc.). However, in the case of a smart city there is a key difference: that is the pervasive presence of technology in the environment and in the hands of the citizens, which makes it possible to implement initiatives that are not possible elsewhere. Thus, smart city environments typically use cutting-edge technology (IoT, edge-clouds, communications networks, etc.). In addition, most of the citizens carry any mobile device (phones, wearables, etc.). This combination turns cities into great laboratories for experimenting and launching new blockchain initiatives.

Another success factor of the solution for city-administration is the development of smart contracts. The implementation of smart contracts enables a significant increase in the possibilities of reinventing the way things are done and extraordinarily simplifies the city administration process.

5. Discussion

The new technologies have changed the current lifestyle, from education and leisure to the way we govern, manage and produce goods and services. Blockchain technology has proved to be a disruptive element that allows innovation or reinvention of strategies that promote social welfare and improve quality of life. The set of solutions identified in this work has made it possible to verify how this technology has the potential to have a positive impact on citizens' living conditions and collaborating decisively in the achievement of the SDGs.

With a huge gap between the resources available and those required to guarantee social assistance to all people in a particularly vulnerable situation, the public authorities and the humanitarian sector are aware that it is a priority to promote innovative strategies to adequately address all current challenges. The identification of all these initiatives and the advantages they provide, suggests that blockchain, together with other emerging technologies, has the potential to create new strategies for action and reinvent existing ones to improve the quality of life of citizens.

Usage of blockchain in public sector is a way for building trust between government and citizens. Based on transparency achieved through decentralization allows all participating actors to see and verify data. The decentralized structure builds confidence as it does not require to trust central authorities.

The data stored on blockchain are safe, they are protected by its replication as well as on a level of access to the particular part of it. The replication of the data also increases its credibility as it is very hard to modify information without any traces. Programmable blockchain transactions enable automatizing of the processing business processes by execution of the procedures, for example, the value transferring between two parties without the need to have trust established between them. This gives the control over particular process, reducing the number of mistakes and errors as well as reducing workload and ensure data integrity.

However, despite all the benefits Blockchain can offer, this technology is not free from limitations (Kshetri, 2017; Alnes et al., 2017; Zwitter & Boisse-Despiaux, 2018), and technical challenges that remain to be addressed, including congestion of communication networks (Kshetri, 2017; Thakur et al., 2020; Zwitter & Boisse-Despiaux, 2018), the lack of blockchain specialists (Thakur et al., 2020), illegal cryptocurrency-related activities (Kshetri, 2017; Lapointe & Fishbane, 2019; Thompson, 2019; Zbinden & Kondova, 2019; Zwitter & Boisse-Despiaux, 2018), and the lack of maturity of technology (Ammous, 2015; Mavilia & Pisani, 2020; Thakur et al., 2020; Thylin & Duarte, 2019). The following limitations have been identified arising from underlying conditions in the humanitarian sector to address city and social issues. These limitations should be taken into account if an implementation is intended to deliver practical and successful results:

Lack of knowledge and information on technology in the population: Being a decentralized technology, achieving citizen understanding and participation is as crucial as the proper development of the technical aspects of a project (Shang & Price, 2019). However, as with many emerging technologies, most research focuses on adopting blockchain for specific groups (Kshetri, 2020; Schuetz & Venkatesh, 2020). It is necessary to promote a process of learning and adapting to technology amongst the general population and other stakeholders, with the aim of understanding how technology is being used and what problems it is able to solve (Kshetri, 2017; Scott et al., 2017; Shang & Price, 2019; Thylin & Duarte, 2019; Wen-kai, 2020).

Political will: Lack of political motivation and lack of knowledge of technology by political representatives could be barriers that prevent blockchain-based initiatives from being implemented (Daniel & Ifejika Speranza, 2020; Kshetri, 2017). Overcoming these barriers could be much more difficult if in fact, political stakeholders see Blockchain as a threat and therefore oppose its use. In this sense, there could be a relationship with the previous challenge, that is, with the lack of knowledge and information of technology. Government participation is required as its capacity and institutional infrastructure can guarantee the quality of the necessary data, contributing to the success and long-term sustainability of the solutions implemented (Daniel & Ifejika Speranza, 2020; Mavilia & Pisani, 2020; Shang & Price, 2019).

Lack of a regulatory framework and standardization: As with many emerging technologies, the absence of regulatory standards and the difficulties in adapting traditional regulatory methods to blockchain work mechanics causes some mistrust in some stakeholders to deploy Blockchain-based applications (Kshetri, 2017; Thakur et al., 2020; Thylin & Duarte, 2019; Zbinden & Kondova, 2019). It is also unclear what role local and governmental authorities should play with regard to regulation (Kshetri, 2017). So far, major regulatory initiatives have focused on the use of cryptocurrencies and not on the technology that supports them (Zbinden & Kondova, 2019).

In addition, cryptocurrencies have negative connotations among population due illicit and illegal activities around it (Mora, 2019).

Incompatibility with existing legislation: Despite the improvement it can entail in the services offered, the collection and storage of large amounts of public data, the lack of a regulatory framework of technology also raises concerns related to data protection and citizens' privacy (Kshetri, 2017; Thompson, 2019; Zwitter & Boisse-Despiaux, 2018). In addition, information stored in a blockchain cannot be modified or deleted, which could be interpreted as an incompatibility with the right to be forgotten (Kshetri, 2017; Zwitter & Boisse-Despiaux, 2018). This context provides the conditions for the risk of developing solutions that violate human rights and data legislation.

Environments with infrastructure constraints: Many countries have limited technological infrastructures (Kshetri, 2017, 2020; Thylin & Duarte, 2019), there are areas and communities that do not have Internet access and electricity (Daniel & Ifejika Speranza, 2020; Mavilia & Pisani, 2020). Faced with these limitations, people's ability to benefit from a Blockchain-based implementation would be hampered by the lack of connectivity (Kshetri, 2020; Thylin & Duarte, 2019).

Application cost: Due to the consensus algorithms on which Blockchain is based, investment in building adequate infrastructure to support the technology can represent an initial increase in cost (Thakur et al., 2020; Wen-kai, 2020; Zbinden & Kondova, 2019). In addition, the immutable nature of Blockchain can also cause the costs of making changes to solution logic to be much higher compared to traditional database systems (Thylin & Duarte, 2019; Zbinden & Kondova, 2019). These considerations may be a barrier in the context of the humanitarian sector, where resources and infrastructure may be limited.

Costs associated with energy consumption: The decentralized nature of Blockchain makes the technology energy inefficient (Kshetri, 2017; Zbinden & Kondova, 2019; Zwitter & Boisse-Despiaux, 2018), which could lead to problems in achieving other priority objectives such as responsible resource consumption and respect for the environment (Thompson, 2019; Thylin & Duarte, 2019). In the humanitarian sector, the costs of maintaining the energy resources needed to support a Blockchain infrastructure can be seen as a barrier that could limit the deployment of many solutions, this being due to the financial constraints of institutions that promote social welfare (Thylin & Duarte, 2019).

The challenges described show that the Blockchain-based approach of initiatives should not be considered generically, especially in the social context, where the formulation of solutions to address the problems affecting the population depends heavily on the cultural, social, political and economic context of each region. Otherwise, there would be a risk of falling into technological determinism where the motivation of solutions is based on the popularity of technology, rather than the needs to be addressed, which would lead to unexpected or unconvincing results in addressing social problems.

To this end, it is recommended to promote the discussion to find useful strategies to anticipate weaknesses in the planning of a solution. It is also necessary to develop methodologies to address the challenges identified in this work and that act as barriers to the efficient use of technology. To do so, it is fundamental the cooperation and participation of the different interested entities, both to improve the technology and the protocols that support it, and to agree on common standards and at the same time, promote a process of formulating a regulatory framework always taking into account the citizen as the central axis.

6. Conclusions

Addressing social problems responsibly is now a priority issue for world leaders and political representatives. This is demonstrated by the acceptance and commitment that many countries have made to meeting the Sustainable Development Goals (SDGs), whose adoption was based on the ethical principle of "*that no one will be left behind*" (United Nations, 2020a). Social challenges have been documented in the literature, providing data that supports the impact and negative consequences they have on the socio-economic development of a region and its citizens.

With this in mind, in this work, a comprehensive review of the solutions of blockchain technology to address the society challenges is described. The proposals demonstrate the potential of this technology in various sectors, including social welfare, where the deployment of solutions based on blockchain can have a significant impact in terms of improving the living conditions of citizens, including those who are in a special situation of vulnerability. As a result, blockchain enables a disruptive change and help to achieve the SDGs. Also, this technology collaborates in the way in which smart cities as human ecosystems can face the challenges of modern societies.

The knowledge about the possibilities of the technology facilitates the collaboration among the academics, researchers, firms, policymakers and other stakeholders to advance in the solutions of society problems. Currently, new tools comprised of models, services and architectures aiming to get the most from this technology. As the research in this field advances, new applications are found to solve existing challenges. Once the advantages of blockchain have been demonstrated, it is expected that a growing number of proposals will be implemented in the real world in the near future.

The results of this review allowed us to draw the border knowledge, to give new application ideas and identify several opportunities for research, within the area of SDGs, smart cities, and blockchain technology. Some described solutions can be applicable to other scopes and problems in the same terms.

However, blockchain is a technology that is still under development and there is still some way to go in terms of social acceptation and the implementation of the solutions in the real world. Therefore, it is recommended to continue exploring new implementation strategies that allow to take advantage of all the benefits that this technology can provide in favour of social welfare.

In addition, it is important to note that these solutions by themselves are not able to achieve the goals. Blockchain technology is just an "enabler" to make easier the implementation of citizen-centric initiatives. But it must also be accompanied by additional measures such as deployment of basic infrastructures (electricity, internet), conducting information campaigns or modernize legislation, among others.

Other limitations of this work come from the applicability target. As mentioned, it is focused on humanitarian sector to address city and social challenges. But the characteristics of these challenges could not be applicable in other sectors. For example, industry or finance sector could have other issues or other concerns to be addressed. In these areas there is a strong will to implement these cost-saving initiatives based on blockchain initiatives.

The future work can take several directions according to subject interested: in first place, to identify social unresolved challenges where the use of blockchain could provide a satisfactory solution, in many cases, in a similar way that described in the existing use cases; secondly, smart city and society challenges are fields where arise interesting research questions about purposes of the technology that could help researches in the field of blockchain for proposing approaches to solve problems in emerging areas, and finally, the current applications of the technology provide a wide sample of what works and what does not in blockchain applications. This also provides a valuable practical knowledge to researchers to guide their future work in this topic.

References

Addison, T., Niño-Zarazúa, M., & Tarp, F. (2015). Aid, Social Policy and Development. Journal of International Development, 27(8), 1351–1365. https://doi.org/10.1002/jid.3187

Afzal, M., Huang, Q., Amin, W., Umer, K., Raza, A., & Naeem, M. (2020). Blockchain Enabled Distributed Demand Side Management in Community Energy System With Smart Homes. IEEE Access, 8, 37428–37439. https://doi.org/10.1109/ACCESS.2020.2975233

Agrawal, T. K., Kumar, V., Pal, R., Wang, L., & Chen, Y. (2021). Blockchain-based framework for supply chain traceability: A case example of textile and clothing industry. Computers and Industrial Engineering, 154. https://doi.org/10.1016/j.cie.2021.107130

Ainsworth RT., Alwohaibi M., Cheetham M (2016). Vatcoin: the GCC's cryptotaxcurrency. Boston Univ. School of Law, Law and Economics Research Paper, (17-04). http://dx.doi.org/10.2139/ssrn.2916321

Allam Z. (2021) Global Tourism and the Risks of Cultural Homogeneity in Smart and Future Cities. In: The Rise of Autonomous Smart Cities. Sustainable Urban Futures. Palgrave Macmillan, Cham. https://doi.org/10.1007/978-3-030-59448-0_6

Allessie D., Sobolewski M., Vaccari L. (2019) Blockchain for digital government, Science for Policy report by the Joint Research Centre (JRC), European Commission. Available online at: https://www.ospi.es/export/sites/ospi/documents/documentos/Tecnologias-habilitantes/Blockchain-for-digital-government_JRC.pdf, accessed on: 15/02/2021.

AlMuhairi, M.O. (2020) Why COVID-19 Makes the Case for Wider Blockchain Integration. Available online: https://www.weforum.org/agenda/2020/05/why-covid-19-makes-a-compelling-case-for-wider-integration-of-blockchain/, accessed on 17/02/2021.

Ammous, S. (2015). Economics beyond Financial Intermediation: Digital Currencies' Possibilities for Growth, Poverty Alleviation, and International Development. Journal of Private Enterprise, 30(Fall 2015), 19–50. https://ideas.repec.org/a/jpe/journl/1196.html

Antal C.D., Cioara T., Antal M., Anghel I. (2021) Blockchain platform for COVID-19 vaccine supply management, available online at: https://arxiv.org/abs/2101.00983, accessed on 17/02/2021.

Arcade City Inc. (2020). Now live in early access. Retrieved October 5, 2020, from https://arcade.city/

Argento L. et al., (2021) ID-Service: A Blockchain-Based Platform to Support Digital-Identity-Aware Service Accountability, Applied Sciences 11(1), 165; https://doi.org/10.3390/app11010165

Asamoah K.O. et al., (2020) Zero-Chain: A Blockchain-Based Identity for Digital City Operating System, IEEE Internet of Things Journal, 7 (10): 10336 – 10346. https://doi.org/10.1109/JIOT.2020.2986367

Barański S., Szymanski J., Sobecki A., Gil D., Mora H. (2020). Practical i-voting on stellar blockchain. Applied Sciences, 10(21):7606:1-22. https://doi.org/10.3390/app10217606

Barrientos, A. (2010). Social Protection and Poverty. UNRISD Flagship Report: Combating Poverty and Inequality, 42, 1–17. Available online at: https://www.unrisd.org/80256B3C005BCCF9/(httpPublications)/973B0F57CA78D834C12576DB003BE255?OpenDocument&cntxt=1A348&cookielang=es, accessed on 27/12/2020.

Barrutia, I., Urquizo Maggia, J. A., & Acevedo, S. I. (2019). Cryptocurrencies and blockchain in tourism as a strategy to reduce poverty. Retos, 9(18), 287–302. https://doi.org/10.17163/ret.n18.2019.07

Benedict, S., Rumaise, P., & Kaur, J. (2019). IoT Blockchain Solution for Air Quality Monitoring in SmartCities. In 2019 IEEE International Conference on Advanced Networks and Telecommunications Systems (ANTS) (pp. 1–6). Goa, India. https://doi.org/10.1109/ANTS47819.2019.9118148

Benítez-Martínez F.L., Hurtado-Torres M.V., Romero-Frías E. (2021) A neural blockchain for a tokenizable e-Participation model, Neurocomputing, 423: 703-712. https://doi.org/10.1016/j.neucom.2020.03.116

Bext360. (2019). Supply Chain Digitization. https://www.bext360.com/

Bibri, S.E., Krogstie, J., 2017. Smart sustainable cities of the future: An extensive interdisciplinary literature review. Sustainable Cities and Society 31, 183-212. https://doi.org/10.1016/j.scs.2017.02.016

Biswas S. et al. (2020) Blockchain for E-Health-Care Systems: Easier Said Than Done, Computer, 53(7): 57 – 67. https://doi.org/10.1109/MC.2020.2989781

Blakstad, S., Allen, R., Blakstad, S., & Allen, R. (2018). Leapfrogging Banks in Emerging Markets. In FinTech Revolution (pp. 121–132). Springer International Publishing. https://doi.org/10.1007/978-3-319-76014-8_7

Bordel, B., Martin, D., Alcarria, R., & Robles, T. (2019). A Blockchain-based Water Control System for the Automatic Management of Irrigation Communities. IEEE International Conference on Consumer Electronics (ICCE) (pp. 1–2). Las Vegas, USA: IEEE. https://doi.org/10.1109/ICCE.2019.8661940

Bordel, B., Martin, Di., Alcarria, R., & Robles, T. (2019, March 6). A Blockchain-based Water Control System for the Automatic Management of Irrigation Communities. 2019 IEEE International Conference on Consumer Electronics, ICCE 2019. https://doi.org/10.1109/ICCE.2019.8661940

Brandão, A., Mamede, H.S., Gonçalves, R., 2018. A Smart City's Model Secured by Blockchain, in: Mejia, J., Muñoz, M., Rocha, Á., Peña, A., Pérez-Cisneros, M. (Eds.), Trends and Applications in Software Engineering. Springer International Publishing, Cham, pp. 249-260. https://doi.org/10.1007/978-3-030-01171-0_23

Cao, Y., Jia, F., & Manogaran, G. (2020). Efficient Traceability Systems of Steel Products Using Blockchain-Based Industrial Internet of Things. IEEE Transactions on Industrial Informatics, 16(9), 6004–6012. https://doi.org/10.1109/TII.2019.2942211

Cha J., Singh S.K., Kim T.W., Park J.H., (2021) Blockchain-empowered cloud architecture based on secret sharing for smart city, Journal of Information Security and Applications, 57: 102686. https://doi.org/10.1016/j.jisa.2020.102686

Choo K-K.R, Ozcan S., Dehghantanha A., Parizi R.M. (2020) Editorial: Blockchain Ecosystem—Technological and Management Opportunities and Challenges, : IEEE Transactions on Engineering Management, 67 (4): 982 – 987. https://doi.org/10.1109/TEM.2020.3023225

Chrono.tech. (2021). Blockchain HR Software Solutions. https://chrono.tech/

Civic Ledger. (2020). Multi-Award Winning Government Blockchain Company. Retrieved October 5, 2020, from https://civicledger.com/

Cook, B. (2018). World Wide Fund for Nature (WWF). Blockchain: Transforming the seafeood Supply Chain. Blockchain Tuna Project, 1–41.

Cueva-Sanchez, J. J., Coyco-Ordemar, A. J., & Ugarte, W. (2020). A blockchain-based technological solution to ensure data transparency of the wood supply chain. 2020 IEEE ANDESCON, 1–6. https://doi.org/10.1109/ANDESCON50619.2020.9272176

Cutsem, O. Van, Dac, D. H., Boudou, P., & Kayal, M. (2020). Cooperative energy management of a community of smart-buildings : A Blockchain approach. Electrical Power and Energy Systems, 117(August 2019), 105643. https://doi.org/10.1016/j.ijepes.2019.105643

Daniel, D., & Ifejika Speranza, C. (2020). The Role of Blockchain in Documenting Land Users' Rights: The Canonical Case of Farmers in the Vernacular Land Market. Frontiers in Blockchain, 3, 19. https://doi.org/10.3389/fbloc.2020.00019

Darilek, P. (2020). A closer look: water & poverty. https://thewaterproject.org/resources/twp-handouts.pdf

Datta A. (2021) Blockchain Enabled Digital Government and Public Sector Services: A Survey. Blockchain and the Public Sector. Public Administration and Information Technology, vol 36. Springer, Cham. https://doi.org/10.1007/978-3-030-55746-1_8

De Tazoult, C. T., Chiky, R., & Foltescu, V. (2019). A Distributed Pollution Monitoring System: The Application of Blockchain to Air Quality Monitoring. Computational Collective Intelligence. ICCCI 2019. Lecture Notes in Computer Science (Vol. 11684, pp. 688–697). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-030-28374-2

Diniz E.H. et al., (2020) Solidarity cryptocurrencies as digital community platforms, Information Technology for Development, https://doi.org/10.1080/02681102.2020.1827365

DOVU. (2018). How the world's first mobility cryptocurrency will create a ubiquitous reward ecosystem for the transport industry. Getting Data Moving. https://dovu.io/whitepaper.pdf

Dua, A., Dutta, A., Zaman, N., & Kumar, N. (2020). Blockchain-based E-waste Management in 5G Smart Communities. In IEEE INFOCOM 2020 - IEEE Conference on Computer Communications Workshops (INFOCOM WKSHPS) (pp. 195–200). Toronto, ON, Canada. https://doi.org/10.1109/INFOCOMWKSHPS50562.2020.9162845

Esposito C., Ficco M., Gupta B. (2021) Blockchain-based authentication and authorization for smart city applications, Information Processing & Management, 58(2): 102468. https://doi.org/10.1016/j.ipm.2020.102468

Everledger. (2020). Everledger uses blockchain to help everyone trust in what they buy. https://www.everledger.io/

Fang, Z., Wei, Z., Wang, X., & Xie, W. (2020). A Blockchain Consensus Mechanism for Marine Data Management System, Blockchain and Trustworthy Systems. BlockSys 2020. Communications in Computer and Information Science (Vol. 1267, pp. 18–30). Springer. https://doi.org/10.1007/978-981-15-9213-3

Figorilli, S., Antonucci, F., Costa, C., Pallottino, F., Raso, L., Castiglione, M., Pinci, E., Del Vecchio, D., Colle, G., Proto, A.,

Sperandio, G., & Menesatti, P. (2018). A Blockchain Implementation Prototype for the Electronic Open Source Traceability of Wood along the Whole Supply Chain. Sensors, 18(9), 3133. https://doi.org/10.3390/s18093133

Fraga-Lamas, P., & M. Fernández-Caramés, T. (2020). Leveraging Blockchain for Sustainability and Open Innovation: A Cyber-Resilient Approach toward EU Green Deal and UN Sustainable Development Goals. In Computer Security Threats. IntechOpen. https://doi.org/10.5772/intechopen.92371

França, A. S. L., Neto, J. A., Gonçalves, R. F., & Almeida, C. M. V. B. (2019). Proposing the use of blockchain to improve the solid waste management in small municipalities. Journal of Cleaner Production. https://doi.org/10.1016/j.jclepro.2019.118529

Francisco, K., & Swanson, D. (2018). The Supply Chain Has No Clothes: Technology Adoption of Blockchain for Supply Chain Transparency. Logistics, 2(1), 2. https://doi.org/10.3390/logistics2010002

Fukuda, K. (2020). Science, technology and innovation ecosystem transformation toward society 5.0. International Journal of Production Economics, 220, 107460. https://doi.org/10.1016/j.ijpe.2019.07.033

GainForest. (2021). USD gained for Nature. https://gainforest.app/#/

Gaudry P., Golovnev A. (2020). Breaking the encryption scheme of the Moscow internet voting system. International Conference on Financial Cryptography and Data Security, pages 32-49. Springer.

Germann M., Serdült U. (2017) Internet voting and turnout: Evidence from Switzerland. Electoral Studies, 47:1-12.

GiveTrack. (2019). The future of philanthropy built upon Bitcoin and Blockchain - Revolutionary donation platform. https://www.givetrack.org/project-details/29/Building-Afghanistan-2.0-w%2F-%23AfghanGirlsCode

Grover B.A. (2021) Blockchain and Governance: Theory, Applications and Challenges. Blockchain for Business: How it Works and Creates Value, Scrivener Publishing LLC. https://doi.org/10.1002/9781119711063.ch6

Guarda T., Augusto M.F., Haz L., Díaz-Nafría J.M. (2021) Blockchain and Government Transformation. Information Technology and Systems. ICITS 2021. Advances in Intelligent Systems and Computing, vol 1330. Springer, Cham. https://doi.org/10.1007/978-3-030-68285-9_9

Guo, C., Ma, S., Wang, H., Cheng, S., & Wang, T. (2018). LoC: Poverty Alleviation Loan Management System Based on Smart Contracts. IEEE International Conference on Internet of Things (IThings) and IEEE Green Computing and Communications (GreenCom) and IEEE Cyber, Physical and Social Computing (CPSCom) and IEEE Smart Data (SmartData), 1527–1532.

Haddouti, S. El, & Ech-Cherif El Kettani, M. D. (2019). Analysis of identity management systems using blockchain technology. Proceedings - International Conference on Advanced Communication Technologies and Networking, CommNet 2019. https://doi.org/10.1109/COMMNET.2019.8742375

Han, Y., Park, B., Jeong, J., Han, Y., Park, B., & Jeong, J. (2019). A Novel Architecture of Air Pollution Measurement Platform Using 5G and Blockchain for Industrial IoT Applications. Procedia Computer Science, 155(2018), 728–733. https://doi.org/10.1016/j.procs.2019.08.105

Hemanth U.M.V.V., Manikanta N., Venkatesh M., Visweswara Rao M., Nandan D. (2021) Impact Study of Internet of Things on Smart City Development. Lecture Notes in Electrical Engineering, vol 698. Springer, Singapore. https://doi.org/10.1007/978-981-15-7961-5_93

Heston, T. F. (2017). A Blockchain Solution to Gun Control. Preprint. https://doi.org/10.7287/peerj.preprints.3407v1

Hou H. (2017). The application of blockchain technology in e-government in china. International Conference on Computer Communication and Networks (ICCCN), pages 1-4.

Howson, P. (2019). Tackling climate change with blockchain. In Nature Climate Change (Vol. 9, Issue 9, pp. 644–645). Nature Publishing Group. https://doi.org/10.1038/s41558-019-0567-9

Howson, P. (2020a). Building trust and equity in marine conservation and fisheries supply chain management with blockchain. Marine Policy, 115, 103873. https://doi.org/10.1016/j.marpol.2020.103873

Howson, P. (2020b). Climate Crises and Crypto-Colonialism: Conjuring Value on the Blockchain Frontiers of the Global South. Frontiers in Blockchain, 3. https://doi.org/10.3389/fbloc.2020.00022

Hua, W., Jiang, J., Sun, H., & Wu, J. (2020). A blockchain based peer-to-peer trading framework integrating energy and carbon markets. Applied Energy, 279. https://doi.org/10.1016/j.apenergy.2020.115539

Idrees SM, Nowostawski M, Jameel R (2021) Blockchain-Based Digital Contact Tracing Apps for COVID-19 Pandemic Management: Issues, Challenges, Solutions, and Future Directions, JMIR Med Inform 2021;9(2):e25245. https://doi.org/10.2196/25245

Jain, S., & Simha, R. (2018). Blockchain for the Common Good: A Digital Currency for Citizen Philanthropy and Social Entrepreneurship. IEEE International Conference on Internet of Things (IThings) and IEEE Green Computing and Communications (GreenCom) and IEEE Cyber, Physical and Social Computing (CPSCom) and IEEE Smart Data (SmartData), 1387–1394.

Jennath HS, Adarsh S, Chandran NV, Ananthan R, Sabir A and Asharaf S (2019) Parkchain: A Blockchain Powered Parking Solution for Smart Cities. Frontiers in Blockchain. 2:6. https://doi.org/10.3389/fbloc.2019.00006

Ji T., Chen J-H., Wei H.H., Su Y-C. (2021) Towards people-centric smart city development: Investigating the citizens' preferences and perceptions about smart-city services in Taiwan, Sustainable Cities and Society, 67: 102691. https://doi.org/10.1016/j.scs.2020.102691

Johanning, S., & Bruckner, T. (2019). Blockchain-based Peer-To-Peer Energy Trade: A Critical Review of Disruptive Potential. International Conference on the European Energy Market, EEM, 2019-September. https://doi.org/10.1109/EEM.2019.8916268

Johnson, L. P., Islam, A., Gogerty, N., & Zitoli, J. (2015). Connecting the Blockchain to the Sun to Save the Planet. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.2702639

Kamath, R. (2018). Blockchain for Women Next Generation for Sustainable Development Goal 5. Asian Development Perspectives, 1, 88–109. https://doi.org/10.22681/ADP.2018.9.1.88

Khalid, R., Javaid, N., Member, S., Almogren, A., Member, S., & Zuair, M. (2020). A Blockchain-Based Load Balancing in Decentralized Hybrid P2P Energy Trading Market in Smart Grid. IEEE Access, 8, 47047–47062. https://doi.org/10.1109/ACCESS.2020.2979051

Khan, M.A., Salah, K., 2018. IoT security: Review, blockchain solutions, and open challenges. Future Generation Computer Systems 82, 395-411. https://doi.org/10.1016/j.future.2017.11.022

Khan, P., Byun, Y.-C., & Park, N. (2020). A Data Verification System for CCTV Surveillance Cameras Using Blockchain Technology in Smart Cities. Electronics, 9(3), 484. https://doi.org/10.3390/electronics9030484

Kim, H., & Laskowski, M. (2018). Agriculture on the Blockchain: Sustainable Solutions for Food, Farmers, and Financing. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.3028164

Kolydas T. (2019). Timestamping metadata using blockchain: A practical approach. Research Conference on Metadata and Semantics Research, pages 451-458. Springer.

Koniyo, M. H., & Sudarma, M. (2020). Data retrieval service on poverty blockchain-based on regional government. Bulletin of Social Informatics Theory and Application, 4(1), 6–11. https://doi.org/10.31763/businta.v4i1.246

Krishnapriya S., Greeshma S., (2020) Securing Land Registration using Blockchain, Procedia Computer Science, 171: 1708-1715. https://doi.org/10.1016/j.procs.2020.04.183

Kshetri, N. (2017). Potential roles of blockchain in fighting poverty and reducing financial exclusion in the global south. In Journal of Global Information Technology Management (Vol. 20, Issue 4, pp. 201–204). Taylor and Francis Inc. https://doi.org/10.1080/1097198X.2017.1391370

Kshetri, N. (2020). Blockchain-Based Financial Technologies and Cryptocurrencies for Low-Income People: Technical Potential Versus Practical Reality. Computer, 53(1), 18–29. https://doi.org/10.1109/MC.2019.2951977

Kshetri, N., & Voas, J. (2018). Blockchain in Developing Countries. IT Professional, 20(2), 11–14. https://doi.org/10.1109/MITP.2018.021921645

La' Zooz. (2017). New application for ride sharing. Available online at: http://lazooz.org/, accessed on 27/12/2020.

Lapointe, C., & Fishbane, L. (2019). The Blockchain Ethical Design Framework. Innovations: Technology, Governance, Globalization, 12(3–4), 50–71. https://doi.org/10.1162/inov_a_00275

Lee J-H (2017) BIDaaS: Blockchain Based ID As a Service, IEEE Access, 6: 2274 – 2278. https://doi.org/10.1109/ACCESS.2017.2782733

Lee, B. S., Song, J. G., Moon, S. J., Park, I. H., & Jang, J. W. (2019). Blockchain Architectures for P2P Energy Trading Between Neighbors. International Conference on Information and Communication Technology Convergence (ICTC) (pp. 1013–1017). Jeju Island, South Korea: IEEE. https://doi.org/10.1109/ICTC46691.2019.8939856

Leite, G. S., & Albuquerque, A. B. (2020). Opportunities for application of blockchain in the scenario of intelligence and investigation units. Advances in Intelligent Systems and Computing, 1226 AISC, 399–414. https://doi.org/10.1007/978-3-030-51974-2_39

Lemieux V.J (2017). Blockchain and distributed ledgers as trusted recordkeeping systems. Future Technologies Conference (FTC), volume 2017

Li, Z., Bahramirad, S., Paaso, A., Yan, M., & Shahidehpour, M. (2019). Blockchain for decentralized transactive energy management system in networked microgrids. The Electricity Journal, 32(4), 58–72. https://doi.org/10.1016/j.tej.2019.03.008

LLC (2021) Liverpool Local Pound. Available online at: https://www.pound-liverpool.co.uk/. accessed on 16/02/2021

Lynch, S. (2018). OpenLitterMap.com – Open Data on Plastic Pollution with Blockchain Rewards (Littercoin). Open Geospatial Data, Software and Standards, 3(6), 1–10. https://doi.org//10.1186/s40965-018-0050-y

Mahmoud, H. H. M., Wu, W., & Wang, Y. (2019). Secure Data Aggregation Mechanism for Water Distribution System using Blockchain. International Conference on Automation and Computing (ICAC) (pp. 1–6). Lancaster, United Kingdom: Chinese Automation and Computing Society in the UK - CACSUK. https://doi.org/10.23919/IConAC.2019.8895146

Maouriyan, N., & Krishna, A. G. A. (2019). AQUACHAIN -Water Supply-Chain management using Distributed Ledger Technology. In 2019 3rd International Conference on Computing and Communications Technologies (ICCCT) (pp. 204–207). Chennai, India: IEEE. https://doi.org/10.1109/ICCCT2.2019.8824945

Martins, V., Oyelere, S. S., Tomczyk, L., Barros, G., Akyar, O., Eliseo, M. A., Amato, C., & Silveira, I. F. (2019). A Blockchain Microsites-Based Ecosystem for Learning and Inclusion. Brazilian Symposium on Computers in Education (Simpósio Brasileiro de Informática Na Educação - SBIE), 30(1), 229. https://doi.org/10.5753/cbie.sbie.2019.229

Mashamba-Thompson, T.P.; Crayton, E.D. (2020) Blockchain and Artificial Intelligence Technology for Novel Coronavirus Disease 2019 Self-Testing. Diagnostics 2020, 10, 198. https://doi.org/10.3390/diagnostics10040198

Mavilia, R., & Pisani, R. (2020). Blockchain and catching-up in developing countries: The case of financial inclusion in Africa. African Journal of Science, Technology, Innovation and Development, 12(2), 151–163. https://doi.org/10.1080/20421338.2019.1624009

Mendoza-Tello JC., Mora H., Pujol-López FA., Lytras MD., (2019) Disruptive innovation of cryptocurrencies in consumer acceptance and trust, Information Systems and e-Business Management 17 (2-4), 195-222. https://doi.org/10.1007/s10257-019-00415-w

Mihaylov, M., Jurado, S., Avellana, N., Van Moffaert, K., De Abril, I. M., & Nowé, A. (2014). NRGcoin: Virtual currency for trading of renewable energy in smart grids. International Conference on the European Energy Market, EEM. https://doi.org/10.1109/EEM.2014.6861213

Mishra, A., Shrestha, R., Kim, S., & Rajput, N. S. (2020). Blockchain for Intelligent Gas Monitoring in Smart City Scenario. Blockchain Technology for Smart Cities, Blockchain Technologies (pp. 59–75). Singapore: Springer. https://doi.org/10.1007/978-981-15-2205-5

Misuraca, G., Viscusi, G., & Pasi, G. (2016). Digital Governance Challenges for ICT-Enabled Innovation of Social Protection Systems in the EU. Electronic Government and Electronic Participation, 23: 172–179. IOS PRESS. https://doi.org/10.3233/978-1-61499-670-5-172

Mora H., Gilart-Iglesias V., Pérez-delHoyo R., Andújar-Montoya MD., Compañ Gabucio HJ. (2016) Interactive cloud system for the analysis of accessibility in smart cities, International Journal of Design & Nature and Ecodynamics 11 (3), https://doi.org/447-458. 10.2495/DNE-V11-N3-447-458

Mora H., Morales-Morales M.R., Pujol-López F.A., Mollá-Sirvent R. (2021b) Social cryptocurrencies as model for enhancing sustainable development, Kybernetes, https://doi.org/10.1108/K-05-2020-0259

Mora H., Peral J., Ferrández A., Gil D., Szymanski J. (2019b) Distributed architectures for intensive urban computing: a case study on smart lighting for sustainable cities, IEEE Access 7, 58449-58465. https://doi.org/10.1109/ACCESS.2019.2914613

Mora H., Pérez-delHoyo R., Sirvent R.M., Gilart-Iglesias V. (2019a) Management City Model Based on Blockchain and Smart Contracts Technology. Research & Innovation Forum 2019. RIIFORUM 2019. Springer Proceedings in Complexity. Springer, Cham. https://doi.org/10.1007/978-3-030-30809-4_28

Mora H., Pujol-López F.A., Morales-Morales M.R., Mollá-Sirvent R. (2020) Disruptive Technologies for Enabling Smart Government, Research and Innovation Forum 2020, Springer Proceedings in Complexity, https://doi.org/10.1007/978-3-030-62066-0_6

Mora H., Varela-Guzmán E., Visvizi A., Mollá-Sirvent R. (2021a) Introduction to a Support Model Based on Cryptocurrencies for Social Inclusion Projects, Research and Innovation Forum 2020, Springer Proceedings in Complexity, https://doi.org/10.1007/978-3-030-62066-0_1

Munir, M. S., Bajwa, I. S., & Cheema, S. M. (2019). An intelligent and secure smart watering system using fuzzy logic and blockchain. Computers and Electrical Engineering, 77, 109–119. https://doi.org/10.1016/j.compeleceng.2019.05.006

Ngo D. (2019) Mongolia's Capital City to Pilot Blockchain Payment System, CoinJournal. Available online at: https://coinjournal.net/news/mongolia-capital-city-to-pilot-blockchain-payment-system/, accessed on 16/02/2021.

Nguyen D.C., Pathirana P.N., Ding M., Seneviratne A., (2020) Integration of Blockchain and Cloud of Things: Architecture Applications and Challenges, Communications Surveys & Tutorials IEEE, 22(4): 2521-2549. https://doi.org/10.1109/COMST.2020.3020092

Nguyen, T. H., Partala, J., & Pirttikangas, S. (2019). Blockchain-based Mobility-as-a-Service. In 2019 28th International Conference on Computer Communication and Networks (ICCCN) (pp. 1–6). Valencia, Spain: IEEE. https://doi.org/10.1109/ICCCN.2019.8847027

Niya, S. R., Jha, S. S., Bocek, T., & Stiller, B. (2018). Design and Implementation of an Automated and Decentralized Pollution Monitoring System with Blockchains, Smart Contracts, and LoRaWAN. In NOMS 2018 - 2018 IEEE/IFIP Network Operations and Management Symposium (pp. 1–4). Taipei: IEEE. https://doi.org/10.1109/NOMS.2018.8406329

Noor, S., Yang, W., Guo, M., Dam, K. H. Van, & Wang, X. (2018). Energy Demand Side Management within micro-grid networks enhanced by blockchain. Applied Energy, 228(April), 1385–1398. https://doi.org/10.1016/j.apenergy.2018.07.012

O'Hara, K. (2018). Where Shall We Draw the Line? Conservatism, Privacy and Digital Modernity. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.3262386

Ølnes S., Ubacht J., Janssen M. (2017). Blockchain in government: Benefits and implications of distributed ledger technology for information sharing. Government Information Quarterly, 34(3):355-364. https://doi.org/10.1016/j.giq.2017.09.007

Orsini, L., Kessler, S., Wei, J., & Field, H. (2018). How the brooklyn microgrid and transactive grid are paving the way to next-gen energy markets. In The Energy Internet: An Open Energy Platform to Transform Legacy Power Systems into Open Innovation and Global Economic Engines (pp. 223–239). Elsevier. https://doi.org/10.1016/B978-0-08-102207-8.00010-2

Pérez-delHoyo R., García-Mayor C., Mora H., Gilart-Iglesias V., Andújar-Montoya M.D. (2017). Improving urban accessibility: a methodology for urban dynamics analysis in smart, sustainable and inclusive cities. International Journal of Sustainable Development

and Planning, 12 (3):357-367. https://doi.org/10.2495/SDP-V12-N3-357-367

Rathee G., Saini H. (2021) Electronic Voting Application Powered by Blockchain Technology, Large-Scale Data Streaming, Processing, and Blockchain Security, IGI Global. https://doi.org/10.4018/978-1-7998-3444-1.ch011

Recereum. (2017). Recereum White paper. Available online at: https://recereum.com/files/WhitePaper-Recereum.pdf, accessed on 27/12/2020.

Rehman M.H., Salah K., Damiani E., Svetinovic D., (2020) Trust in Blockchain Cryptocurrency Ecosystem, IEEE Transactions on Engineering Management, 67(4): 1196 – 1212. https://doi.org/10.1109/TEM.2019.2948861

Reinsberg, B. (2019a). Blockchain technology and the governance of foreign aid. Journal of Institutional Economics, 15(3), 413–429. https://doi.org/10.1017/S1744137418000462

Ripe.io. (2015). Blockchain for food. https://www.ripe.io/

Rivera R., Robledo J.G., Larios V.M., Avalos J.M (2017) How digital identity on blockchain can contribute in a smart city environment, International Smart Cities Conference (ISC2). https://doi.org/10.1109/ISC2.2017.8090839

Roztocki, N., Soja, P., & Weistroffer, H. R. (2019). The role of information and communication technologies in socioeconomic development: towards a multi-dimensional framework. Information Technology for Development, 25(2), 171–183. https://doi.org/10.1080/02681102.2019.1596654

Rupasinghe, T., Burstein, F., Rudolph, C., & Strange, S. (2019). Towards a Blockchain based Fall Prediction Model for Aged Care. ACM International Conference Proceeding Series, 1–10. https://doi.org/10.1145/3290688.3290736

Saleh, H., Avdoshin, S., & Dzhonov, A. (2019). Platform for tracking donations of charitable foundations based on blockchain technology. Proceedings - 2019 Actual Problems of Systems and Software Engineering, APSSE 2019, 182–187. https://doi.org/10.1109/APSSE47353.2019.00031

Schmelz, D., Strobl, S., Niemeier, P., & Grechenig, T. (2019). Technical mechanics of a trans-border Waste Flow Tracking solution based on Blockchain technology. In 2019 IEEE 35th International Conference on Data Engineering Workshops (ICDEW) (pp. 31–36). Macao,Macao: IEEE. https://doi.org/10.1109/ICDEW.2019.00-38

Schuetz, S., & Venkatesh, V. (2020). Blockchain, adoption, and financial inclusion in India: Research opportunities. International Journal of Information Management, 52, 101936. https://doi.org/10.1016/j.ijinfomgt.2019.04.009

Scott, B., Loonam, J., & Kumar, V. (2017). Exploring the rise of blockchain technology: Towards distributed collaborative organizations. Strategic Change, 26(5), 423–428. https://doi.org/10.1002/jsc.2142

Shang, Q., & Price, A. (2019). A Blockchain-Based Land Titling Project in the Republic of Georgia: Rebuilding Public Trust and Lessons for Future Pilot Projects. Innovations: Technology, Governance, Globalization, 12(3–4), 72–78. https://doi.org/10.1162/inov_a_00276

Shi, Z., Liang, J., Pan, J., & Chen, J. (2019). How IoT and Blockchain Protect Direct-Drinking Water in Schools. IEEE Internet of Things Magazine, 2(4), 2–4. https://doi.org/10.1109/MIOT.2019.8982735

Sinha S., Pradhan C. (2021) Blockchain Technology Enabled Digital Identity Management in Smart Cities. In: Security and Privacy Applications for Smart City Development. Studies in Systems, Decision and Control, vol 308. Springer, Cham. https://doi.org/10.1007/978-3-030-53149-2_7

Smart4Tech. (2019). Smart4tech – Sustainable Transformation. Retrieved from https://smart4.tech/

Søgaard J.S. (2021) A blockchain-enabled platform for VAT settlement, International Journal of Accounting Information Systems, https://doi.org/10.1016/j.accinf.2021.100502

Soni D.B., Mahler M.L., (2020) Blockchain Technology for a Firearm Registry, New Zealand Journal of Business &Technology, 2: 34-42.

Stocker, A., & Stephens, S. (2019). Evaluating the Potential of Cooperative Ridesourcing: A Case Study of Arcade City in Austin, Texas. https://arcade.city/files/ArcadeCity_FinalReport.pdf

Stukach, V., Starovoytova, N., Dolmatova, O., & Evdokhina, O. (2019). Domestic food assistance to vulnerable groups: infrastructure, social nutrition, organic agriculture. MPRA Paper, 1–8. Available online at: https://ideas.repec.org/p/pra/mprapa/99673.html, accessed on 27/12/2020.

SunContract. (2017). Decentralized Energy Market. Available online at: https://suncontract.org/res/whitepaper.pdf, accessed on 27/12/2020.

Tangcharoensathien, V., Mills, A., Das, M. B., Patcharanarumol, W., Buntan, M., & Johns, J. (2018). Addressing the health of vulnerable populations: Social inclusion and universal health coverage. Journal of Global Health, 8(2). https://doi.org/10.7189/jogh.08.020304

Tangcharoensathien, V., Srisookwatana, O., Pinprateep, P., Posayanonda, T., & Patcharanarumol, W. (2017). Multisectoral actions for health: Challenges and opportunities in complex policy environments. In International Journal of Health Policy and Management, 6 (7): 359–363. Kerman University of Medical Sciences. https://doi.org/10.15171/ijhpm.2017.61

Thakur, V., Doja, M. N., Dwivedi, Y. K., Ahmad, T., & Khadanga, G. (2020). Land records on Blockchain for implementation of Land Titling in India. International Journal of Information Management, 52, 101940. https://doi.org/10.1016/j.ijinfomgt.2019.04.013

Theodorou S., Sklavos N (2019) Blockchain-Based Security and Privacy in Smart Cities, Smart Cities Cybersecurity and Privacy, 21-37. https://doi.org/10.1016/B978-0-12-815032-0.00003-2

Thompson, C. (2019). Opportunities and Challenges in Applying Distributed Ledger Technologies in Global Supply Chains for Social Good. Frontiers in Blockchain, 2. https://doi.org/10.3389/fbloc.2019.00011

Thylin, T., & Duarte, M. F. N. (2019). Leveraging blockchain technology in humanitarian settings–opportunities and risks for women and girls. Gender and Development, 27(2), 317–336. https://doi.org/10.1080/13552074.2019.1627778

Treiblmaier H. et al., (2020) Blockchain as a Driver for Smart City Development: Application Fields and a Comprehensive Research Agenda, smart cities, 3, 853–872. https://doi.org/10.3390/smartcities3030044

Tsolakis, N., Niedenzu, D., Simonetto, M., Dora, M., & Kumar, M. (2020). Supply network design to address United Nations Sustainable Development Goals: A case study of blockchain implementation in Thai fish industry. Journal of Business Research. https://doi.org/10.1016/j.jbusres.2020.08.003

Turk Z., Klinc R. (2017) Potentials of Blockchain Technology for Construction Management, Procedia Engineering, 196:638-645. https://doi.org/10.1016/j.proeng.2017.08.052

Uddin, M. (2021). Blockchain Medledger: Hyperledger fabric enabled drug traceability system for counterfeit drugs in pharmaceutical industry. International Journal of Pharmaceutics, 597, 120235. https://doi.org/10.1016/j.ijpharm.2021.120235

Unicef. (2018). StaTwig: Improving food and vaccines distribution systems more efficiently through blockchain. Available online at: https://www.unicef.org/innovation/stories/statwig-improving-food-and-vaccines-distribution-systems-more-efficiently-through, accessed on 27/12/2020.

United Nations. (2015). Transforming our World: The 2030 Agenda for Sustainable Development. Available online at: https://sdgs.un.org/publications/transforming-our-world-2030-agenda-sustainable-development-17981, accessed on 20/12/2020.

United Nations. (2019). Global Sustainable Development Report 2019 - The future is now - Science for achieving sustainable development. New York. Available online at: https://sustainabledevelopment.un.org/content/documents/24797GSDR_report_2019.pdf, accessed on 20/12/2020.

United Nations. (2020a). About the Sustainable Development Goals. https://www.un.org/sustainabledevelopment/sustainable-development-goals/, accessed on 20/12/2020.

United Nations. (2020b). Take Action for the Sustainable Development Goals. Available online at: https://www.un.org/sustainabledevelopment/sustainable-development-goals/, accessed on 26/12/2020.

Villares, L. (2021). Blockchain and Conservation: Why Does It Matter. Applications in Payments for Ecosystem Services and Bolsa Floresta Program. Proceedings of Smart Innovation, Systems and Technologies (Vol. 198, pp. 346–355). Springer International

Publishing. https://doi.org/10.1007/978-3-030-55374-6_34

Wang, Z., Wang, T., Hu, H., Gong, J., Ren, X., & Xiao, Q. (2020). Blockchain-based framework for improving supply chain traceability and information sharing in precast construction. Automation in Construction, 111, 103063. https://doi.org/10.1016/j.autcon.2019.103063

Wen-kai, W. (2020). Application of Blockchain in Targeted Poverty Alleviation. 186–188. https://doi.org/10.2991/aebmr.k.200306.032

Wijaya D.A., Liu J.K, Suwarsono D.A., Zhang P (2017). A new blockchain-based value-added tax system. In International conference on provable security, 471-486. Springer. https://doi.org/10.1007/978-3-319-68637-0_28

Yang L., Elisa N., Eliot N., (2019) Privacy and Security Aspects of E-Government in Smart Cities, Smart Cities Cybersecurity and Privacy, 89-102. https://doi.org/10.1016/B978-0-12-815032-0.00007-X

Zbinden, F., & Kondova, G. (2019). Economic Development in Mexico and the Role of Blockchain. Advances in Economics and Business, 7(1), 55–64. https://doi.org/10.13189/aeb.2019.070106

Zhang, D. (2019). Application of Blockchain Technology in Incentivizing Use of Rural Wastes: A of case study on Yitong System. Energy Procedia, 158, 6707–6714. https://doi.org/10.1016/j.egypro.2019.01.018

Zhang, K., Ni, J., Yang, K., Liang, X., Ren, J., Shen, X.S., 2017. Security and Privacy in Smart City Applications: Challenges and Solutions. IEEE Communications Magazine 55, 122-129. https://doi.org/10.1109/MCOM.2017.1600267CM

Zhang, X., & Wang, D. (2019). Adaptive Traffic Signal Control Mechanism for Intelligent Transportation Based on a Consortium Blockchain. IEEE Access, 7, 97281–97295. https://doi.org/10.1109/ACCESS.2019.2929259

Zhang, Y., Sun, W., & Xie, C. (2019). Blockchain in Smart City Development—The Knowledge Governance Framework in Dynamic Alliance. Advancements in Smart City and Intelligent Building. ICSCIB 2018. Advances in Intelligent Systems and Computing (Vol. 890, pp. 137–152). Springer. https://doi.org/10.1007/978-981-13-6733-5_13

Zwitter, A., & Boisse-Despiaux, M. (2018). Blockchain for humanitarian action and development aid. Journal of International Humanitarian Action, 3(1), 16. https://doi.org/10.1186/s41018-018-0044-5