AREAS OF BLOCKCHAIN TECHNOLOGY APPLICATION
IN MODERN CITY – PART I

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Purpose: The purpose of paper is to indicate the potential of using blockchain technology in smart cities. The author analyzes the state of development of blockchain-based solutions and relates it to areas of the functioning of cities. The aim is also to indicate blockchain applications importance in the context of city residents quality of life and the functioning of various industries operating within them.

Design/methodology/approach: The objectives of the paper were achieved by analyzing literature, industry reports as well as selected blockchain projects' websites. The theoretical scope of the article is the description of blockchain technology application areas within the modern cities, their main characteristics and the potential for its usage.

Findings: The author indicated 6 areas of blockchain application, and then indicated a number of functioning solutions based on blockchain referring to them, and also indicated the potential of the impact of the described solutions on the development of the city. In the summary, areas for further research were indicated, referring to slightly differently perceived aspects of the city's development and improving the lives of its inhabitants.

Practical implications: The successful implementation of blockchain solutions depends on a large amount of conceptual and technological work in organizations. The article suggests areas of blockchain use in the city and indicates examples of already implemented solutions that can constitute a reference point and inspiration for new solutions.

Social implications: The blockchain technology shows the potential to improve the quality of life of city residents in the context of building solutions that eliminate the need for trust in service providers, weakened by frequently observed unethical behavior and negligence in the security and transparency of information flow. The widespread use of blockchain in the city is therefore undoubtedly in the interest of societies.

Originality/value: The paper's originality is expressed in a comprehensive look at the issue of using blockchain in the functioning of modern cities, together with an indication of both the potential of their implementation and already existing solutions in the subject area. Moreover, the author points out social benefits in the form of increased trust and an increase in the city residents quality of life.

Keywords: from 3 to 5 keywords (phrases), justified text, spacing before 6 pt., TNR 12 pt. font, single line spacing.

Category of the paper: Literature review, viewpoint.

1. Introduction

Modern cities are characterized by dynamic development, trying to meet the challenges related to the increasing level of urbanization, sustainable development and effective management of resources (Addas, 2023; Sodiq et al., 2019). In this context, the role of technology becomes crucial, and one of the most innovative ones, gaining more and more recognition, is blockchain technology (Radu, 2020; Choi et al., 2022). Blockchain, originally known as the basis for the functioning of cryptocurrencies, shows the potential for a revolutionary transformation within smart cities, offering not only secure and non-retroactive data storage, but also opening new opportunities in areas such as urban infrastructure management, services for citizens, identification, transport, and environmental and health protection (Ante, 2020). This article reviews the main areas of application of blockchain technology in the context of smart cities, analyzing their potential, benefits and challenges related to the implementation of this innovative solution in processes aimed at developing the city and improving the quality of people's lives. The title of this article suggests that its topic will be published in two papers. The first one focuses on three areas of application of blockchain technology in modern cities: management of food supply chains, the functioning of the tourism industry within cities and intelligent healthcare for its residents. The second article in the series will refer to the telecommunications industry, the energy sector and intelligent transport systems and will be published in one of the next issues of the magazine. In the second part, the topics outlined in this introduction will also be expanded to include aspects related to the administrative management of the city and civic participation and its enhancement thanks to the use of blockchain technology.

2. Materials and methods

A literature review - in particular bibliometrics - was carried out for research without the publishing time limitation on the topic of blockchain technology for smart city area of research. The first step was to analyze publications included in the Scopus database. However, for a comprehensive study, the analysis was deepened to include the Web of Science database. The following queries were run on October 16th 2023:

- Scopus: TITLE-ABS-KEY ("blockchain AND smart AND city").
- Web of Science: TOPIC: ("blockchain smart city"); Indexes: SCIEXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI, CCREXPANDED, IC.

The search results showed given numbers of publications in subject area: Scopus – 1767, Web of Science – 1511.

Figure 1 shows the number of publications on analyzed topics since 2016 in both analyzed databases.
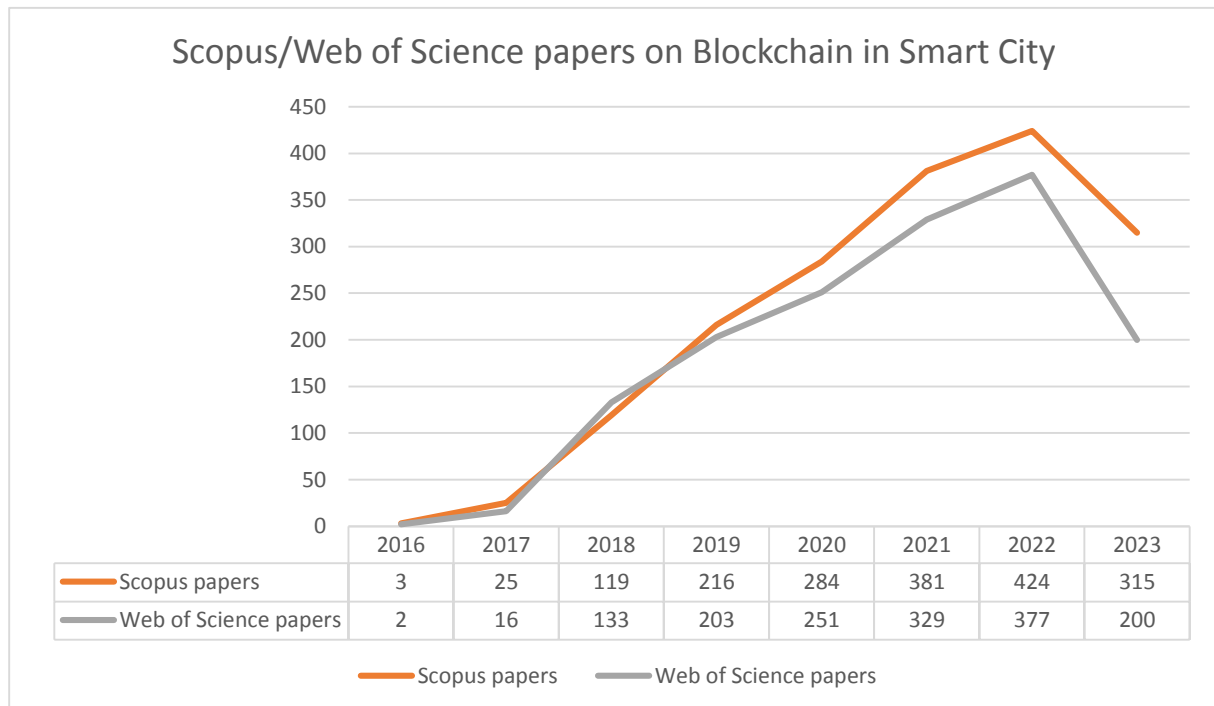

Figure 1. Scopus papers on Blockchain in Smart City.

Source: own elaboration.

The search results indicate a relatively big number of publications embedding the topic of blockchain technology in the field of smart city, which confirms the author's assumptions about the popularity of chosen topic and legitimacy of in-depth analyzes in this area. The graph of the number of papers in the analyzed area clearly shows an upward trend, signaling the constantly growing interest of researchers in the applications of blockchain technology in the area of city management. During the preparation of this article, the literature review resulting from the above bibliometric analyzes was supplemented with a review of reports from analytical and consulting companies as well as a review of selected blockchain projects websites.

3. Blockchain technology applications in the context of smart city

In the era of dynamic changes in the area of urban development and technology, the concept of Industry 4.0 is the foundation of the digital revolution, transforming not only the methods of industrial production, but also introducing significant innovations in the context of smart cities (Safiullin, Krasnyuk, Kaplyuk, 2019; Lepore, Testi, Pasher, 2023). In this context, blockchain technology, which is one of the main pillars of Industry 4.0, plays a key role as a tool enabling effective, secure and transparent data management in urban environments (Javaid et al., 2021).

This article analyzes contemporary solutions based on blockchain technology, positioning them within the concept of smart city and Industry 4.0. The focus was on exploring the ways in which blockchain technology can support the development of smart cities by optimizing processes, improving infrastructure, providing services to residents and creating innovative solutions that constitute the foundation for sustainable urban development in the digital era (Zaczyk, 2022). The issue of the basics of the functioning of blockchain technology and smart contracts was discussed in previous scientific articles by the author of this publication (Zaczyk, 2021), as well as in numerous articles by other authors, therefore it is not discussed in this paper (Warburg, Wagner, Serres, 2019).

Nowadays, developing cities are designed in such a way that it is possible to organize them effectively in the conditions of increasing urbanization, the need to control CO_2 emissions and improving the quality of life of residents thanks to the extensive use of modern ICT technologies (Yusoff, 2020). ICT technologies contribute to the dynamic development of various types of subsystems of the city management system (Tcholtchev, Schieferdecker, 2021). These include the healthcare system, energy management, water management, urban transport system, tourism, food supply chains, education system and many others. The main components of the smart cities concept are presented in Figure 2.
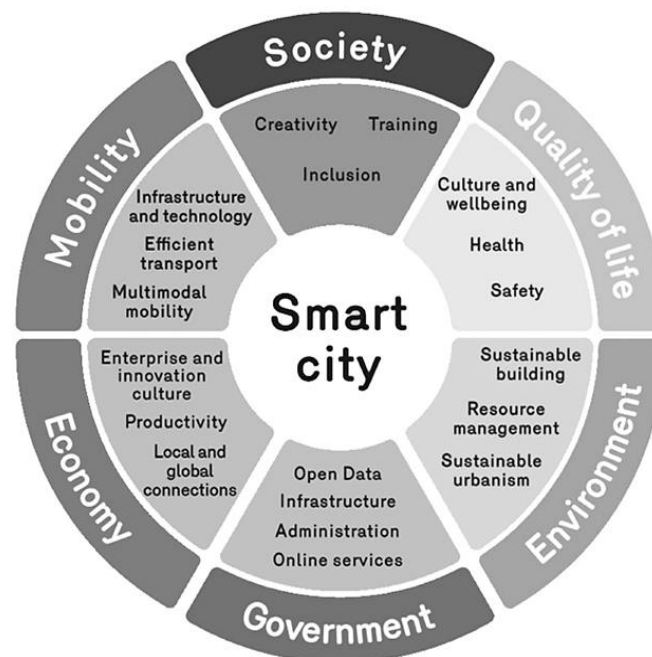

Figure 2. Main components of Smart cities.

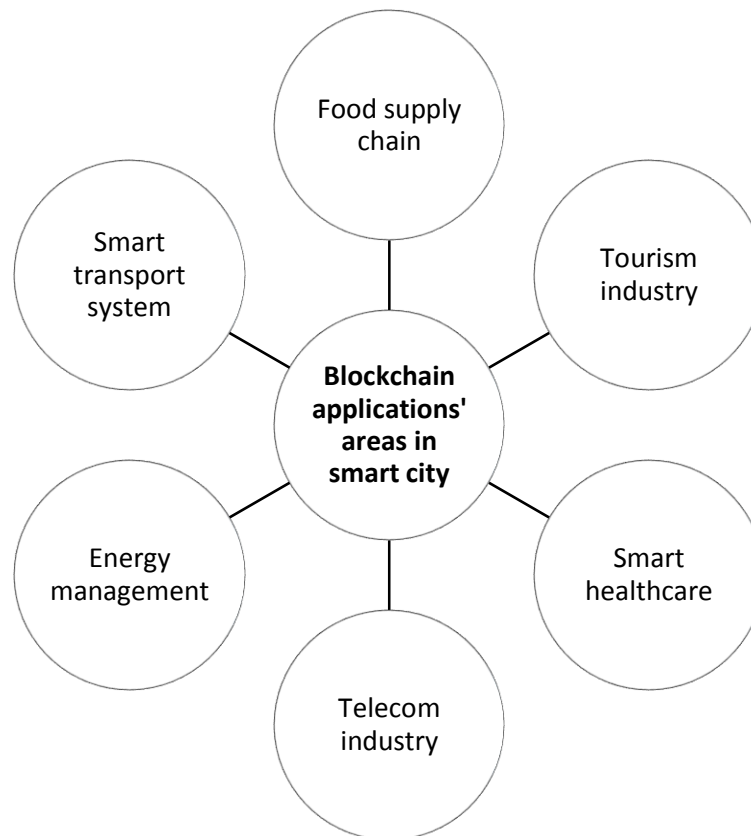Source: Qureshi, Hadi, Haroon, Bashir, Islam, 2020, pp. 75-92.

Figure 3. Scopus papers on Blockchain and Artificial Intelligence in Supply Chain Management.

Source: own elaboration based on Ullah, Naeem, Coronato, Ribino, De Pietro, 2023.

The applications of blockchain technology are increasingly being mentioned among the key factors transforming the functioning of modern cities (Treiblmajer, Rejeb, Strebinger, 2020). The combination of a wide network of IoT devices, 5G (or even 6G) technology and blockchain technology shows great potential to increase the security of IT processes that improve processes carried out in a modern, smart city (Singh et al., 2020). Blockchain-based systems are able to ensure greater data security, privacy of their users and enable process automation using smart contracts (Gupta et al., 2020). Applications of blockchain technology can be found in many areas of city management, such as: food supply chains, tourism industry, intelligent healthcare, telecommunications industry, energy management, and intelligent transport systems (Ullah et al., 2023).

3.1. Blockchain solutions for food supply chain

Food supplies are an essential part of people's lives in cities. More and more aware consumers demand access to information regarding the sources of origin, degree of processing and storage conditions of food at individual stages of its flow in supply chains (Haji et al., 2020). Blockchain, thanks to its characteristics, ensures a 100% reliable record of the information desired by the customer and enables backtracking of food provenance measured in seconds instead of days, as was the case with more traditional methods (De Conti, 2022).

This has a positive impact on the customer's experience in terms of the safety of the food received, quality compliance verification, and also strengthens data security in the supply chain. The use of blockchain technology in the area of food supply chains involves the use of distributed registers to track all transactions between supply chain participants as well as events related to the flow of goods (Kamilaris, Fonts, Prenafeta-Boldu, 2019). Supply chain links interact with the blockchain ledger using role-specific web and/or mobile applications. An example of the use of blockchain in the food supply chain is the IBM Food Trust (Joo, Han, 2021). The benefits of its use for individual links in the supply chain are indicated in Table 1.

Table 1.
The benefits of the use of IBM Food Trust for links in food supply chain

Food supply chain node	Value added by IBM Food Trust
Growers	-Proving the farm is not a source of outbreak, -connectivity to the supply chain
Food manufacturers	-Instill trust between retails, suppliers and customers -Automated and reduced manual certificate management
Distributors	-Conduct targeted recalls -Enable internal data sharing
Logistic companies	-Enhanced ability to meet compliance standards -Manual processes reduction
Retailers	-Assure customers food supplied is safe -Conduct targeted recalls quickly
Consumers	-Learn about recalls and increased transparency -Reduce risk of being victimized by food fraud
Certification bodies	-Reduce fraudulent certificates -Increase renewal speed
Food services (HORECA)	-Assure customers food supplied is safe -Reduce wasted food
Regulators	-Identify contamination quickly -Reduce unnecessary testing

Source: Zaczyk, 2022.

Analyzing the potential of the practical use of blockchain in the food supply chain, there are numerous examples of solutions already operating in the industry. Selected of them are indicated in Table 2 (Patel et al., 2022).

Table 2.
Selected blockchain-based solutions for food supply chain management

Solution	Functionality	Source
"Thank my Farmer"	Coffee tracing from its source to the consumption place	thankmyfarmer.com
BC Food Safety Alliance	Imported meat monitoring in the supply chain	jdcorporateblog.com
IBM Food Trust	Collaborative network of growers, processors, wholesalers, distributors, manufacturers, retailers, and others, enhancing visibility and accountability across the food supply chain	ibm.com/products/supply-chain-intelligence-suite/food-trust
Greenfence	Food chain members authentication and recording	gfsi.greenfence.com/
Ripe.io	Supply chain tracking, secure data aggregation and business model digitization, farming processes automation	ripe.io
TagOne	Identification of data tempering, providing clear audit trails and track global natural supply imbalances	tagone.com

Cont. table 2.

Transparent Path	Farm-to-distributor journey of food in real-time displaying	xparent.io
Wholechain	Product information digitizing, tracking of food quality data and coordination between parties during the delivery process	wholechain.com
FoodLogicQ	Supplier documentation centralization, product evaluations facilitation and food recall actions automation	foodlogiq.com
Mojix	Food safety compliance automation, expiration date tracking and inventory management	mojix.com
AgriDigital	Building a profitable, equitable and sustainable future for agricultural businesses and their communities	agridigital.io

Source: own elaboration.

The solutions presented in Table 2 are largely based on smart contracts and enable deepening relationships between supply chain participants, eliminating the need for trust within it and bringing benefits to all its participants, as shown in the example of IBM Food Trust (Table 1). The examples listed in Table 2 are solutions dedicated to the supply chains of a specific food product (coffee, meat) or solutions treating the food supply chain more broadly - as a coherent logistics system.

3.2. Blockchain solutions for tourism industry

Tourism is an area where cities and regions can look to increase their attractiveness and encourage many people to visit them (Khairi, Darmawan, 2021). Blockchain technology based solutions are also used in this area. There is possibility to find them in many areas related to tourism such us (Erol et al., 2022):

- booking systems – the use of smart contracts can revolutionize booking systems, which will gain the ability to automate the management of reservations and payments while minimizing the involvement of intermediaries and ensuring trust thanks to the software,
- identity authentication and verification – eliminating the need to use physical documents, reducing the risk of fraud and fraudulent activities,
- loyalty programs and rewards - increasing the transparency and flexibility of the solutions used,
- destination tracking and management - accurate and reliable tracking of tourist movements and behaviors, tourists' activities real-data capturing,
- reputation systems and reviews – verifying reviews coming from customers of tourism industry companies of different types.

Examples of applications of blockchain technology in the area of broadly understood tourism are indicated in Table 3.

Table 3.
Examples of blockchain-based solutions in tourism industry

Solution	Functionality	Source
Trippki	A blockchain-based project that aims to create better customer loyalty schemes in the travel and tourism industry	blog.trippki.com
ShoCard and SITA	Improving the identity management in the travel industry through blockchain	crunchbase.com/organization/shocard-inc
Krispay	Digital wallet allowing Singapore Airlines customers to turn their FFPs into payments which are developed by KPMG and Microsoft	singaporeair.com/en_UK/sg/ppsclub-krisflyer/use-miles/krispay/
Lockchain	A direct market place for many hotels, airlines and more. It uses the decentralized system for payment, property management, booking process and lot more	lockchain.ai
Bed-swap	Ability to move inventories between various points of sale and selling margins, launched by TUI	forbes.com/sites/bernardmarr/2018/12/07/the-amazing-ways-tui-uses-blockchain-to-revolutionize-the-travel-industry/
BeeToken	Home-sharing platform with the usage of blockchain technology to put customers in contacts with hosts, so that they can arrange and pay for stays	beetoken.com
Winding Tree	Baggage tracking via blockchain and a booking platform	windingtree.com

Source: own elaboration.

In the area of tourism industry, there are currently relatively few solutions based on blockchain technology, but there are still several existing solutions with varying degrees of development (Table 3). Existing solutions, although not very well developed and at an early stage of their life cycle, show the way for the development of blockchain-based tools aimed at improving the functioning of the tourism sector, which significantly influences the attractiveness of a modern city.

3.3. Blockchain solutions for smart healthcare

The healthcare area plays a key role in the functioning of a smart city for several reasons (Al-Azzam, M.K., Al-Azzam, M.B., 2019). Firstly, healthy residents are the foundation of productivity and quality of life in the city (Mouratidis, 2021). Secondly, advanced medical technologies and e-health are an integral part of intelligent systems, enabling health monitoring, rapid response to health threats and improving access to health care (Idoudi, Val, 2021). Additionally, effective health services help reduce the burden on the care system, ensuring faster and more effective action in crisis situations, which is important for the stability and safety of smart city residents.

Blockchain technology has the potential to transform healthcare by placing the patient at the center of the healthcare ecosystem and increasing the security, privacy and interoperability of health data (Chang, Chen, 2020). This technology can provide a new model for health information exchange, increasing the efficiency, immediacy and security of electronic health records (Aloini et al., 2023). Examples of applications of blockchain technology in the field of healthcare are indicated in Table 4.

Table 4.

Examples of blockchain-based solutions in the field of healthcare

Solution	Functionality	Source
Akiri Switch	A network-as-a-service optimized specifically for the healthcare industry, helping protect transportation of patient health data. The Akiri system does not store data of any kind. ensures healthcare data remains secure and shareable with only the parties authorized for access at the moment when they need it	healthcareitnews.com/news/blockchain-network-service-platform-scores-10-million-ama-backed-health2047
BurstIQ	Complete and up-to-date information about patients' health and healthcare activity, it could help to root out abuse of opioids or other prescription drugs	burstiq.com
Medicalchain	Maintainin the integrity of health records while establishing a single point of truth. Doctors, hospitals and laboratories can all request patient information that has a record of origin and protects the patient's identity from outside sources	medicalchain.com
Avaneer Health	A public ledger to support better claims processing, secure healthcare data exchanges and keep provider directories maintained and up-to-date	avaneerhealth.com
Patientory.inc	Enabling patients, healthcare providers and clinicians to access, store and transfer all important information via blockchain. Patientory helps the healthcare industry move more quickly by housing all patient information under one roof	patientory.com
Embleema	A virtual trial and regulatory analytics platform designed to fast track drug development. Users are recruited to digitally consent to secure, untampered medical data collection, which is then stored on Embleema's blockchain and analyzed	embleema.com
Blockpharma	A solution for drug traceability and counterfeiting. By scanning the supply chain and verifying all points of shipment, the company's app lets patients know if they are taking falsified medicines	Mars, Youssouf, Cheikhrouhou, Turki, 2021, pp. 197-208.
Tierion	Auditing documents, recording drugs and medicines to keep a clear history of possession. The company uses timestamps and credentials to maintain proof of ownership throughout a medical supply chain	tierion.com
FarmaTrust	Tracking pharmaceuticals, determining the authenticity of medical devices, and maintaining data security for patients scheduling vaccinations and diagnostic testing. The company's services help to keep fake drugs out of the supply chain	farmatrust.com

Source: own elaboration.

As proven in Table 4, there are many more blockchain-based solutions in the healthcare space than in the tourism space. Trust in the holders of patients' medical data is absolutely crucial for the functioning of the medical industry, and the use of blockchain allows it to be ensured thanks to technology. A problem that has been plaguing the medical industry for years is the issue of counterfeit drugs circulating in circulation, and blockchain is able to ensure full transparency of the supply chain, thus ensuring the authenticity of medical products and drugs in the possession of patients. This helps to increase trust and confidence in the medicines they use. The use of blockchain technology in the medical industry, in the opinion of the author of this article, is a milestone in its development and gives hope for a significant improvement in the quality of medical services offered to residents of modern, smart cities.

4. Summary

As shown in this article, blockchain technology is already an important pillar of the functioning of many smart city areas. Blockchain-based solutions clearly demonstrate an impact on improving the quality of people's lives and the functioning of many industries that are key to the development of a smart city. By strengthening the transparency of data flow about residents and business entities operating in the city, they enable direct communication between residents, city authorities and the private sector. Transparent access and use of public services, integrity and security of information are the undoubted and unique advantages of blockchain technology. In fact, in each of the areas called key components of a smart city, blockchain technology offers a number of innovative solutions, and the dynamics of their development indicates a further expansion of the spectrum of emerging projects based on this technology.

As for the suggestion regarding future areas of scientific research, it is also worth noting the potential of blockchain-based solutions enhancing civic participation (resident loyalty platforms, complaint management systems), affecting the labor market (certifications and register of references on the blockchain), civic identity and culture (registers of monuments, grants for civil society), land development (land registration, documenting the conditions of real estate), or security (chain of custody on the blockchain, registration of video systems). The jointly developing concept of smart city and one of the pillars of industry 4.0 - blockchain - give hope for improving the functioning of modern cities, the quality of life of their inhabitants and the climate conducive to the development of business within them.

The future areas of research outlined above, as well as the areas of application of blockchain technology in energy, telecommunications and intelligent transport systems, will constitute the pillar of the second part of this article, which will be published as a separate paper. In the opinion of the author of this article, blockchain technology is still an insufficiently appreciated technological invention, the application of which goes far beyond cryptocurrencies perceived as the main use of blockchain. Its advantages can be seen primarily in ensuring trust for supply chain links, public administration units, or any other blockchain users, as well as in ensuring full data transparency. This may contribute to revolutionary changes in the perception of business processes of modern organizations and the functioning of societies around the world.

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