ARTIFICIAL INTELLIGENCE AND BLOCKCHAIN FOR SMART CITY

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Introduction/background: In this article, we want to focus on two very important aspects of a Smart City, which is the use of artificial intelligence and Blockchain in the functioning of cities.
Aim of the paper: The aim of the article is to assess the possibilities of using those technologies implementation of public tasks and in everyday contacts of the public sector with stakeholders.
Materials and methods: The article is theoretical and is based on a review of the literature and examples in the implementation of Artificial Intelligence and Blockchain technology in a smart city.
Results and conclusions: Artificial Intelligence and Blockchain have great potential to support the development of smart city. The dissemination of these technologies is indicated by the Gartner curve for Digital Government Technology. AI (Autonomus Vehicles) and Blockchain are the most impact technologies on government organizations over the next 5 to 10 years AI and Blockchain can provide significant benefits to many areas of the city's functioning: it is a huge database for collecting and analyzing. Blockchain consensus methods allow greater transparency and less susceptibility to manipulation, they increase the tendency of stakeholders to participate and intensify social initiatives.

Keywords: smart city, artificial intelligence, blockchain.

1. Introduction

Smart city are technologically advanced cities where intelligent subsystems connect people and organizations. These cities are able to use large data sets to offer stakeholders real-time access to high-quality public services and thus improve the quality of life in the city. Economic growth is supported by information and communication technologies. They not only improve city management, but also (and maybe above all) stimulated social participation and the sharing idea (Kitchin, 2015). Smart cities are often called digital cities based on new technologies, where ICT solutions, internet of things, big data, cloud computing and Industry 4.0 become reality (Washburn et al., 2010; Albino et al., 2015; Klein, Kaefer, 2008). Omnipresent sensors are changing the way of movement in urban space, increase safety and allow the collection of

large data sets that can be analysed using Artificial Intelligence (AI) algorithms. They allow the city to communicate with its own infrastructure, monitor the movement of its residents and respond to it. As a result, the city's conditions can be optimized. AI has been designed to efficiently collect, analyse and correctly interpret data and respond to it without any human interaction. Although Artificial Intelligence is far from independence for now, but it can learn and constantly improve its activities by collecting and analysing new data that requires appropriate storage and transmission. Blockchain technology is helpful in this regard, as its distributed registry architecture means that data is stored simultaneously on all network nodes. This allows for complete decentralization of data, making access to them more efficient and more "democratic".

Over the past 10 years, Artificial Intelligence and Blockchain have become technologies that promise significant and even ground-breaking innovations. The idea of combining these two technologies in creating a smart city is particularly intriguing. It engages intelligent human capital (Shapiro, 2006; Giffinger et. al., 2007; Lombardi et al., 2012), because only people are able to create and use intelligent solutions for the benefit of the general public. It also indicates the need to develop smart governance, whose task is to create the environment of cooperation and creation of conditions for participatory performance of public tasks.

According to forecasts, the potential benefits of combining Artificial Intelligence with Blockchain can be counted in billions in the near future. These two technologies can develop separately, but together they have bigger potential. As complementary technologies, they can provide significant benefits for all areas of smart city, from Big Data analyzes, through health care and financial services, to social participation and public-private partnership. Blockchain offers artificial intelligence a huge database for collecting and analysing data that remains safe and unchangeable even in case of failure. Blockchain consensus methods allow greater transparency of relations between stakeholders. They also guarantee the confidentiality of data transfers without compromising privacy and security, and less susceptible to manipulation.

Given the above, the purpose of this article is to present the role and significance of Artificial Intelligence and Blockchain in creating of smart city (Fig. 1). The first part presents the concept of smart city from the perspective of ICT technology development, which gave impetus to the development of Artificial Intelligence and Blockchain. In the second part AI functionalities supporting the creation of smart city will be presented. Subsequently, the potential of Blockchain technology and its areas of application in smart city was pointed out. The summary presents the problems that AI and Blockchain can solve and the challenges that integration of both technologies face.

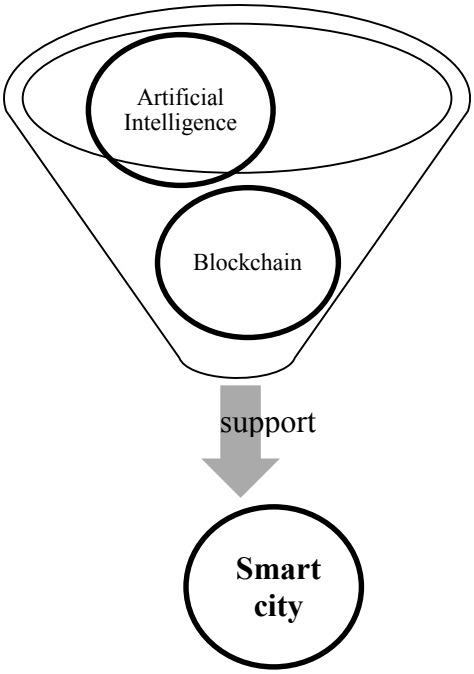

Figure 1. AI and Blockchain as elements supporting Smart City development. Source: own work.

2. Literature review – smart city in the context of ICT Technologies

Although the concept of "smart city" is becoming more and more popular, thus a generally accepted definition has not yet developed. Analysis of the literature in this area allows to distinguish two description ways: 1. city based on ICT (Hollands, 2008; Komninos, 2008), 2. a new paradigm in the city's development, where the key role is played by human and social capital, education and the environment (Neirotti, De Marco, 2014; Giffinger, Fertner et al., 2007; Lombardi, Giordano et al., 2012; Caragliu, Del Bo, Nijkamp, 2009). The technological smart city trend is reflected, among others in the definition of T. Bakici, E. Almirall and J. Wareham (2013), according to which „smart city as a high-tech intensive and advanced city that connects people, information and city elements using new technologies in order to create a sustainable, greener city, competitive and innovative commerce, and an increased life quality". Similarly, IBM defines a smart city: „A city is an interconnected system of systems. A dynamic work in progress, with progress as its watchword. A tripod [infrastructure, operations, people] that relies on strong support for and among each of its pillars, to become a smarter city for all" (IBM, 2015). This definition includes three key features of smart city: 1. instrumented i.e. the presence of ICT solutions in the city (sensors, mobile devices), 2. connected, i.e. the availability of connections between the real and virtual world, using instrumentation and (3) intelligent, meaning the ability to use new technologies in the city's development process (Harrison, Eckman, Hamilton, Hartswick, Kalagnanam, Paraszczak and Williams, 2010).

Proponents of this approach say that cities will be on the verge of a revolutionary breakthrough and will become cities of dreams. Each sphere of life will be digitized, and applications, algorithms and artificial intelligence will reduce congestion, prevent crime and create free public services (Giffinger, Fertner et al., 2012). But will it really be like that? Is the reconfiguration of the city into technological problems enough to make us feel good in the city? Probably not.

The reconstruction of the basics of urban life and city management taking into account only the technological perspective will rather lead to the fact that cities will be superficially intelligent, and deeply full of injustices and inequalities. That is why in local government practice and scientific discourse, the second trend of understanding smart city, which goes far beyond its technocratic perception, increasingly dominates. In this approach, technological solutions only support smart city. Thanks to them, it is easier to combine information and political vision into a coherent program of improving the city and its services. New technologies are an instrument for creating cities that are able to combine physical and social capital, provide better services and good quality infrastructure. This approach is reflected in the definitions of A. Caragliu, Ch. Del Bo and P. Nijkamp (2011), who write: "We believe a city to be smart when investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance". Also N. Komninos (2008), who write „(Smart) cities as territories with high capacity for learning and innovation, which is built-in the creativity of their population, their institutions of knowledge creation, and their digital infrastructure for communication and knowledge management"[1]. From the perspective of the considerations in this study, this approach to smart city seems the most justified. It combines the social and economic dimension, takes into account the need to develop the city while maintaining the principles of sustainable development.

In the context of using ICT, smart city can be defined as "information technology combined with infrastructure, architecture, everyday objects, and even our bodies to address social, economic, and environmental problems" (Towsend, 2013). A smart city is defined as a city in which ICT is merged with classic infrastructures, coordinated and integrated using new digital technologies (Batty, Axhausen et al., 2012). Mitchell M. defines smart city as "intelligence based on the increasingly effective combination of digital telecommunication networks (the nerves), ubiquitously embedded intelligence (the brains), sensors and tags (the sensory organs), and software (the knowledge and cognitive competence)" (Mitchell, 2007). This does not exist in isolation from other urban systems or connected to them only through human intermediaries.

[1] A wider review of the definition of smart city presents: (Albino, Berardi, Dangelico, 2015).

Thanks to the use of ICT, all elements of the city (economy, transport, living, management, education, medicine) can become smarter; can improve the functioning of existing infrastructure and change the approach to planning and urban design. Creating a smart city using Artificial Intelligence and Blockchain will solve some of the city's problems, e.g., in terms of energy efficiency, reducing the arduousness of production processes for the urban environment, making better use of city resources, regulating congestion through an intelligent transport network, increasing the scope of social participation and transparency between stakeholders providing public services.

3. Artificial Intelligence of the future of smart city

Artificial intelligence is a field of computer science that deals with the creation of intelligent devices and machines that will have the ability to respond just like human. Although its history dates back to the 50s of the last centuries (McCarthy, Minsky, Rochester, Shannon , 2006; Kar, Dash, 2018), it was only the progress in designing computing power to store and process large data sets and the potential of the Internet allowed AI to become one of the most powerful technologies of the century. In artificial intelligence, so-called machine learning plays an important role, because it is the basis for the development of learning systems. It is thanks to them that rational and logical reasoning of machines that are able to adapt to changing situations is possible. Importantly, the development of artificial intelligence is parallel to the development of cognitive science, i.e., research on intelligence and the functioning of the human brain. This allows to explore the possibilities of computer-human cooperation. Modern computers, like the human brain, rely on neural networks that deal with the enormity of data, skillfully transforming it. For this reason, they use machine learning, image recognition and natural language processing. Thus, machines equipped with the AI platform[2] are able to collect information from the environment and using logic identify actions with the highest probability of success (Mnih, Kavukcuoglu et al., 2015; Bughin, Hzan et al., 2017).

Artificial Intelligence finds application in many areas of life, including increasingly in smart city, determining its development in all functional areas (smart economy, smart mobility, smart environment, smart people, smart living, smart governance). Examples of smart city support by artificial intelligence algorithms is presented in Table 1. The use of AI is key from the point of view of striving for sustainable urban development. Thanks to AI applications it is possible to optimize the city system, e.g., by monitoring energy consumption (Adio-Moses, Asaolu, 2016) or creating efficient and intelligent transport systems (Agarwa et al., 2016). Infrastructure solutions are already emerging that are capable of introducing automated

[2] Examples are Netflix and Amazon, which use AI to personalize recommendations for millions of subscribers around the world.

operation of urban systems. Thanks to AI platforms it will be possible to introduce autonomous cars to the streets, track the level of air pollution, as well as more efficient and easier management of the urban lighting system. Argawa et al. (2015) emphasize that AI is not only a solution that facilitates the design of urban systems, along with the scheduling of the city's transport or energy system but can also be used to optimize flows. Artificial Intelligence will allow the prediction of road conditions and congestions, generate reports in real time on accidents and other road incidents. This makes it easier to take routine decisions in the field of control and increase traffic flow, especially in those areas of the city that are in danger of congestion.

Table 1.
Examples of smart city support by Artificial Intelligence Algorithms

Smart city dimensions	Examples of AI possibilities
Smart economy	Optimization of city infrastructure, energy and water saving, editing of building maintenance costs, sharing economy
Smart mobility	Autonomous vehicles, prediction of traffic parameters, traffic light control, Information about free parking spaces, reduction of external transport costs, reduction of congestion
Smart environment	pollution reduction, reduction of water and energy consumption, smart bins
Smart people	Create Artificia Intelligence, participation in the public life
Smart living	Smart buildings, intelligent healthcare, prevention of hospitalization, virtual assistance, crime prevention, increasing residents' safety
Smart governance	Participate in decision making, public-private-partnership, Chatbots and automatic replies, e-consultations, crowdfunding

Source: own work.

Thanks to AI, traffic management systems in the city will transform from static to dynamic systems. They will allow to adapt to current conditions in real time, taking into account different types of transport. The introduction of Artificial Intelligence to e.g., a traffic light control system and building a platform for processing interactive data will allow monitoring and predicting traffic behaviour. It will also develop communication plans for different scenarios, allowing for a smooth adaptation to changing conditions. AI can also be a basis for the development of new systems of cooperation for fleet operators and management of cities, enabling e.g. sharing information in real time about traffic congestion or air pollution. As a result, the system will prevent build-up of problems before they occur. A model of traffic management using AI based on neural networks prepares decisions based on the received input data and selects the most appropriate solution for the traffic situation (Fig. 2). Moreover, traffic management systems based on AI can create time plans for intersections, reducing the phenomenon of congestion problems and suggest alternative routes (De Oliviera, Neto, 2013). They can even plan compulsory travel times (to work, school) by activating the alarm clock early. The use of AI in vehicles will allow them to communicate directly with the infrastructure, which will smooth out journeys in urban areas.

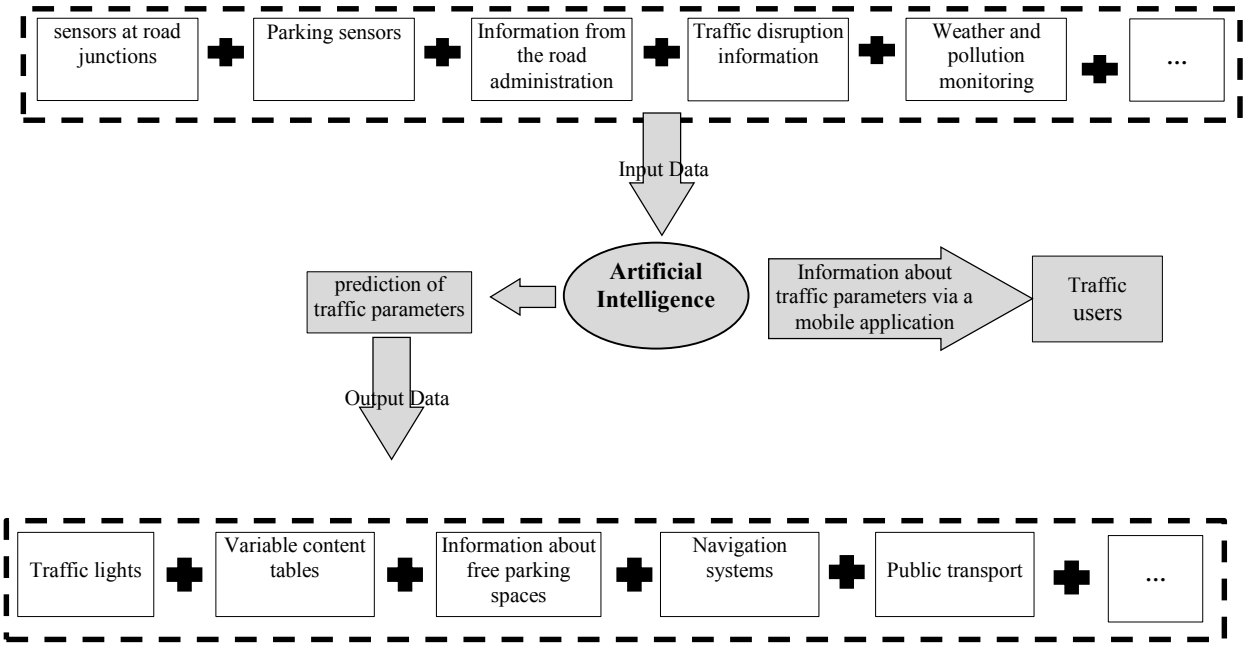

Figure 2. Model of traffic management using Artificial Intelligence. Source: own work.

Artificial Intelligence's capabilities are not limited to traffic management and control. They cover a wide range of applications, from medical diagnostics, through controlling robots and chatbots, to virtual assistance. An example could be predicting places and periods of increased crime, allowing for more efficient planning of city guard and police interventions. Ongoing monitoring of the internet can be an instrument of prevention against attacks on the safety of residents. Big Data analysis and AI predictive capabilities allow better management of operations during emergencies. What's more, AI allows to prevent breakdowns and overloads of energy, water supply, etc. infrastructure and optimize its maintenance. The use of AI in smart buildings allows to implement hundreds of sensors that monitor our preferences and habits. It combines several duties into one control centre - with one remote control or application, which allows to control the operation of air conditioning, ventilation, central heating, lighting, alarm, door locks and home monitoring. This makes it easier to manage and reduce energy consumption. After installing the appropriate sensors (e.g., movement, humidity, light, gas), the system can automatically lower the temperature inside the house, e.g., after opening the window, turn off the light by itself or disconnect unused devices from the power supply, while informing us of any adverse events (Skouby et. al., 2014).

Artificial Intelligence also supports the functioning of the public sector and smart governance. Facilitates contacts with stakeholders and improves service for residents. Chatbots and automatic replies allow to redirect matters to the appropriate departments and create documents in repetitive matters. The issuing of official documents will be monitored. To exclude racist aspects, origin, education, age, gender or beliefs AI can monitor the issuance of decisions on issues of social welfare, as well as search for documents from municipal databases and seem repetitive administrative decisions. It can also use the data provided by

residents, increasing their readiness for social participation. From the perspective of smart governance, citizen participation is key. AI by sharing administrative decisions, e.g. in Blockchain, can significantly increase the transparency of relations between stackeholders, and thus the involvement of citizens in city management.

4. Blockchain in the development of smart city

Blockchain is an innovative technology based on a distributed and widely available data register, which is a collective book of accounts. It allows to save information about each transaction in the form of data blocks that combine into an integral chain. Each block has a unique signature, impossible to forge, and each action must be confirmed by a private key, i.e. a string of characters known only to entities directly involved in the transaction. Only the private key owner can initiate changes (Iansiti, Lakhani, 2017). Blockchain is considered the safest technology for data recording and storage. It allows to associate transactions with computational logic (users can configure it). It is used to record of information about economic events and all financial operations carried out between transaction partners. Blockchain technology uses cryptographic methods to prevent making corrections once entered information without the knowledge of other participants in the system (Pilkington, 2016). That means (Kauf, 2019):

- transaction transparency – every transaction and all its contents are visible to everyone who has access to the domain of a network participant. Each node (user) has a unique alphanumeric character that identifies it. Users can remain anonymous or if transactions occur between block addresses – reveal their identity;
- records irreversibility – once the transaction has been entered into the database, no changes can be made, any modifications are visible to other network participants. The data entered is chronologically and available to everyone.

Blockchain allows the development of relations between entities in a distributed manner, without involving middlemen, coordinators or planners. It does not allow falsification of data and is resistant to manipulation. Blockchain technology supports the functioning of smart city in all its dimensions. Specific implementations of blockchain technology, such as smart contract, smart assets or digital identity facilitate not only the contracts agreements with contractors, but also control of task performance. Based on Smart Contracts and block chains, decision making systems can optimize the activities of entities involved in creating public value, and public e-procurement can prompt the public sector to use negotiated tendering procedures more often. Transaction transparency is a source of benefits for the public sector; allows to increase the efficiency and effectiveness of relationships with contractors and optimize the distribution of Smart Assets. Smart Contracts and Blockchain-based voting, decision, and

negotiation support systems enhance and optimize the operation of the Smart Community (Nasulea, Mic, 2018). Smart city benefits from increased productivity thanks to automated interactions with e-Citizen and optimized distribution of Smart Assets. Fig. 3 presented Blockchain Technology as an integrator of smart city entities. Blockchain allows access to the registry for all members of the community. Everyone has its own synchronized copy of a common book (Blockchain register).

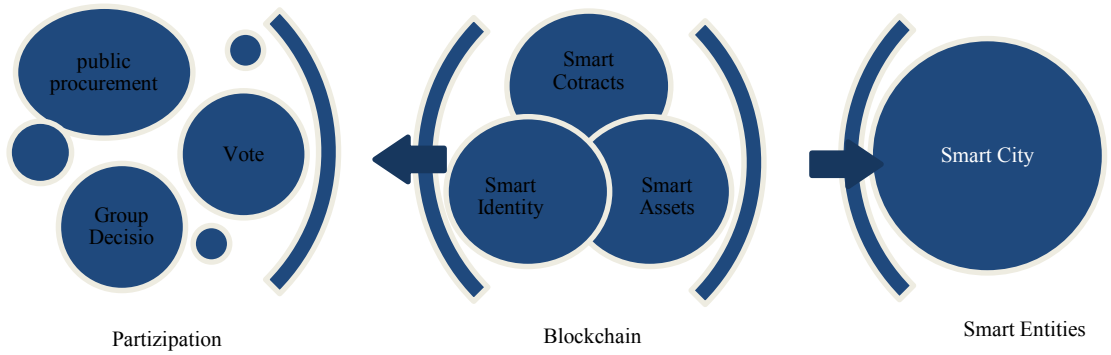

Figure 3. Blockchain Technology as an integrator of smart city entities. Source: own work.

Blockchain technology guarantees high resistance to data manipulation. It secures all stakeholders' access to real and current information. By transforming resources into Smart Assets, smart cities can track the origin and movement of goods (e.g., pharmaceuticals) throughout the value chain for Citizens. This reduces fraud in the distribution of goods and the reaction almost immediately after the detection of the irregularity. Blockchain allows the measurement and recording parameters, which are stored and transported goods, and this is particularly important in the case of sensitive goods (those pharmaceuticals). Stored values are unmodifiable. Thus, Blockchain is an effective tool for supplier verification by smart governance.

Because the choice of supplier in the implementation of public tasks is based on public procurement, it is worth to point out the benefits that Blockchain technology can bring in this area. This technology can contribute to: 1. increasing their efficiency and transparency, 2. reducing fragmentation, and thus the benefits of economies of scale, by implementing a unified electronic platform. It can be assumed that online public procurement processing will become a common practice in the next decade, not only on a local but also on a global scale. The extension of the network will allow, among other banks located in various places around the world to easily send certified electronic guarantees on behalf of the supplier. Blockchain technology will change the conditions for participation in tender procedures. Everyone who wants to participate in the implementation of public tasks will have to use electronic means of communication[3]. This will allow faster and more transparent verification of submitted

[3] From October 2018, all tender procedures from the so-called EU thresholds are implemented using electronic means of communication.

applications. It will create a significant barrier to submitting discounted offers, as once entered data cannot be changed. Each modification will be visible and will require the approval of other stakeholders.

Participation in public e-procurement will force suppliers to have a Digital Identity. The one created using the Blockchain protocol can be used as an electronic signature. Currently, the most interesting application is the Estonian e-Residency program, enabling the user to create a digital identity. It can be used, among others to set up a business by citizens outside the European Union. The combination of digital identity with intelligent assets also opens up the possibility of authorizing resources that are owned by the individual. Those registered in the Blockchain protocol can be used to initiate transactions on our behalf. In practice, this means, for example, automatic planning of technical inspections by public transport vehicles.

Blockchain also agrees to authenticate the digital identity of citizens, and this creates the opportunity to participate in local, regional or national elections, without leaving home. Blockchain guarantees both voice secrecy and verifiability of the number and legality of voters. The chain of blocks will allow every citizen to control the vote. In Blockchain, the citizen remains anonymous, and his voice is public. Due to the dispersion of the database, it cannot be hacked, and it is not threatened by any IT system failures. The voter can vote from any place where he gains access to the network practically from any device that has the character of a computer – which eliminates the risk of extortion of votes, adding them to polls, creating false identities, etc. This way of voting ensures greater confidence in the electoral process, reduces costs and enables decisions to be taken directly by the constituency.

Blockchain technology could also contribute to greater public involvement in the city's life and functioning. In a smart city, decisions do not have to be made as a result of voting, because the classic majority voting system can be replaced by decision systems that require the consent of a larger part of the community. In this case, important social problems could be discussed until the community reaches consensus (Nasulea, Medintu, 2015). In addition, it opens wide opportunities for social initiatives (Crowdfunding).

Although Blockchain technology has a number of applications and allows for various variants of direct democracy, the scope of its use is conditioned by the level of awareness of Smart Governance, or rather policy makers. These relevant laws and ordinances may support or inhibit the use of Blockchain technology. At the moment, it is crucial to create legal regulations that will allow cities to create Smart Contracts that do not require a paper version and a notary signature.

5. Conclusion

The considerations presented in the article show that Artificial Intelligence and Blockchain have great potential to support the development of smart city. They are the most promising innovative technologies, the use of which is almost limitless. The dissemination of these technologies is also indicated by the Gartner curve for Digital Government Technology. It follows, that AI (Autonomus Vehicles) and Blockchain are the most impact technologies on government organizations over the next 5 to 10 years (Fig. 4).

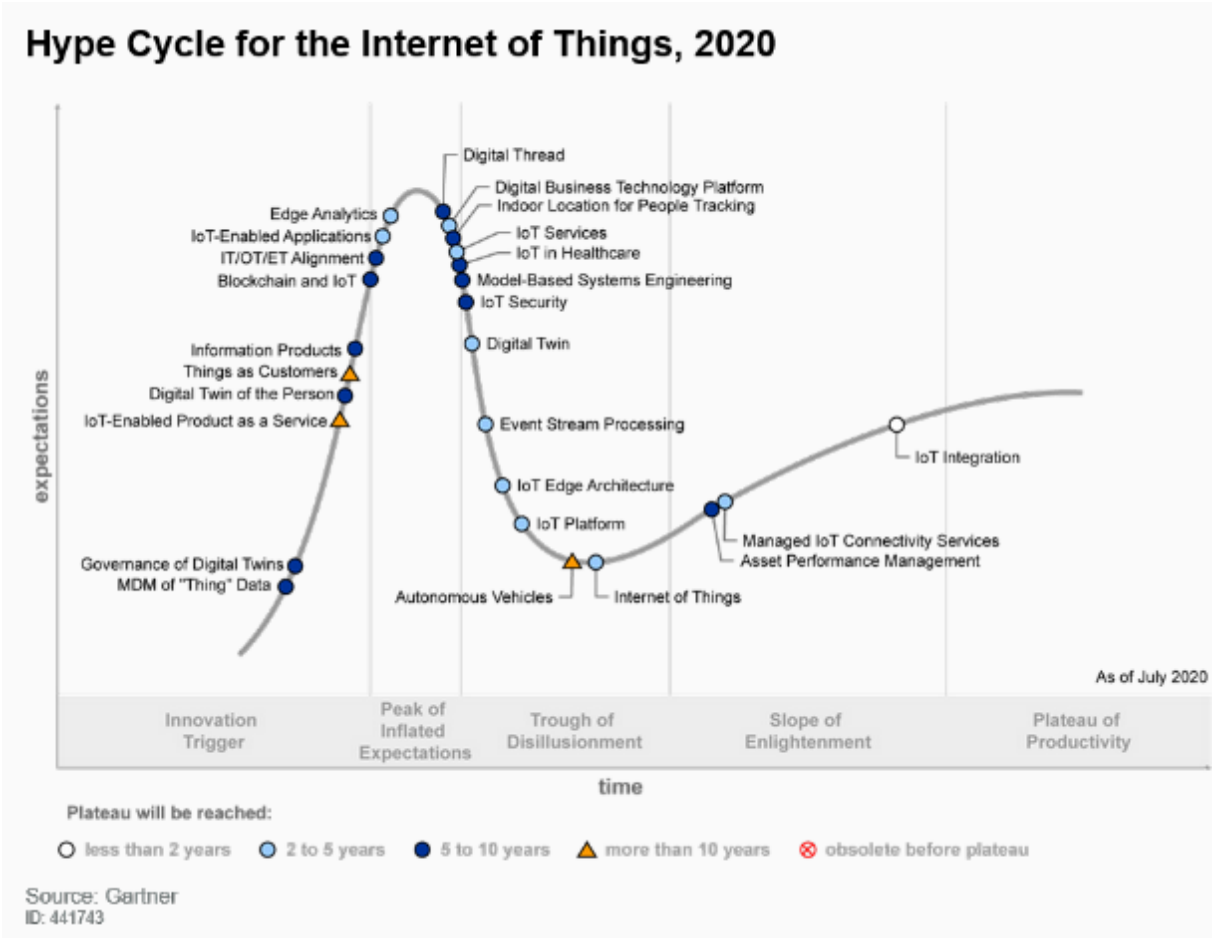

Figure 4. Hype Cycle for the Internet of Things 2020. Source: https://lhpeurope.com/flexibility-in-the-industrial-internet-of-things-iiot/, 14.01.2021.

As complementary technologies, AI and Blockchain can provide significant benefits to many areas of the city's functioning. The earliest concepts of combining AI and blockchain relate to data analysis. Blockchain offers artificial intelligence a huge database for collecting and analysing, as well as centralized data sets. Those in Blockchain stay safe and unchangeable even in the event of a failure. Blockchain consensus methods allow greater transparency and less susceptibility to manipulation. Thus, they increase the tendency of stakeholders to participate and intensify social initiatives. The solutions shown predispose these technologies to the rank of breakthrough innovations, often referred to as destructive technologies.

This is due to the fact that any technology that revolutionizes the current order is destructive. In this case, however, we should refer it rather to the creative destruction that Schumpeter wrote about (1942). Blockchain will transform public services by providing a transparent, authoritative register of public sector transactions and reduce conflicts between public and private sector entities. Artificial Intelligence will be used to serve residents, issue administrative decisions or manage city traffic.

Though the capabilities of AI and Blockchain are huge, their integration still faces many challenges. One of the sources of concern is the issue of privacy, especially when it comes to potentially sensitive data and applicable laws.

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