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BLOCKCHAIN IMPLEMENTATION IN SMART CITIES

With a Deep Dive Use Case: Smart Dubai

RESEARCH PAPER CONDUCTED BY MASTERS STUDENTS OF THE UNIVERSITY OF NICOSIA (CYPRUS)
MASTER OF SCIENCE – BLOCKCHAIN & DIGITAL CURRENCY
MODULE DFIN524 - BLOCKCHAIN APPLICATIONS
JUNE 2019

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Special thanks for their cooperation to **Karm Legal Consultants** based out of Dubai, in giving us valuable insights on Smart Contracts legality, current applications and vision on the future developments of Smart Contracts in Smart Cities.

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INTRODUCTION

Without any doubt technology has played a major part when it comes to the development of cities. From first human settlements to huge impacts like the industrial revolution to today, technological advancements have impacted our lives in many ways.[1] Experts predict that the way we live today will change drastically in the next decades. A huge demographic and social change followed by climate change will impact our lives in the future and will impose an extreme burden on our existing city infrastructures.

In 2050 and for the first time in human history there will be more people living in cities than in the countryside. The UN estimates that there will be roughly 10 billion people living on our planet by 2050[2]. Compared to the current situation (7,7 billion people) there will be almost 3 billion more people living on our planet than there are right now. Also, climate change and the increase in the population won´t be the only problem humanity will have to face by 2050. Providing enough goods and services for people and huge cities will be especially challenging.

Many cities won´t have the capacity for so many people, for instance in many parts of the world the electric grid is not made to provide electricity for such a huge number of inhabitants. The infrastructure must be renewed, and an interdisciplinary way of thinking will be needed. All over the world futurists are working on plans on how to make future cities more liveable for such a massive gain in population.

These imperatives have given rise to the birth of the idea of Smart Cities. Smart Cities is the idea of improving the efficiency of resource usage and facilitating the provision of new services within cities; by adding a digital layer to metropolitan area infrastructures through technology in an intelligent way in order to improve inhabitants' quality of life. Furthermore, Smart Cities aim to save money by reducing costs and also improving sustainability. Smart Cities' purpose is to use technology to enhance liveability. The plan to create Smart Cities is not an easy plan. It needs to integrate communication technology as well as all sorts of information technology, together with important social aspects, to augment the standard of living considering the fact that urbanisation will be increasing drastically in future.

[1] https://theblockchainland.com/2019/03/05/blockchain-role-developing-smart-cities/
[2] https://www.un.org/en/sections/issues-depth/population/

HOW DID THE "SMART CITY" CONCEPT COME TO LIFE?

As stated above, we conclude that the three principal drivers of the requirement for Smart Cities are:

- Anticipated rapid urbanization over the coming decades;
- Climate change;
- Logistical demands.

and the premise that without addressing these three issues, the world's mega-cities are destined to become increasingly chaotic, inefficient and susceptible to being controlled by criminal elements.
"*What will these cities of the future be like? Will they be lively centres of culture and innovation? Or will they be grim hubs of despair as depicted in movies like Metropolis and Blade Runner?*" (Barlow, 2015).

How can the idea of Smart Cities, and in particular the use of Blockchain within the Smart City context, turn this gloomy spectre into an opportunity for growth and development, and what are some of the longer-term implications of Smart Cities for city inhabitants?

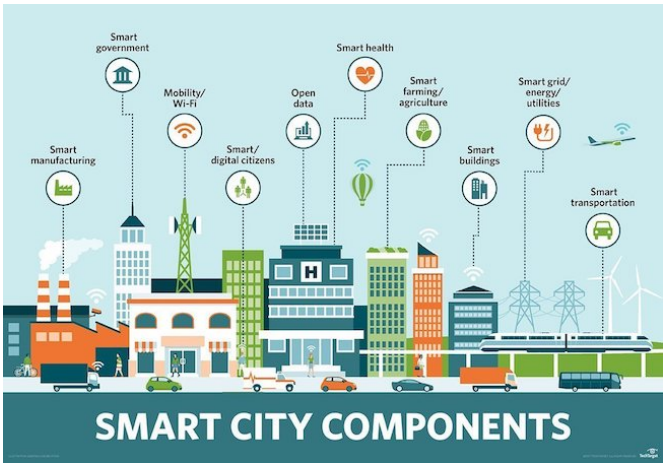
Before discussing these questions in detail, we need to understand what we mean by the term "Smart City" and we need to deep dive into the concept itself. The literature indicates various subtly different definitions of a Smart City, depending on the viewpoint of the respective authors.
For example, Barlow (Barlow, 2015) in citing a paper by Eric McNulty[3] classifies Smart Cities into four types:

- Legacities (Rome, London, New York, Paris);
- Technotopias (Dubai, Singapore, Songdo);
- McCities (Found in recently developing countries like India and China, and are built to accommodate rapidly growing populations, but they rely on traditional construction techniques and materials. They aren't technology paradises, but they are built with the modern economy in mind);

[3] Director of research and professional programs at the National Preparedness Leadership Initiative (NPLI), a joint venture of the Harvard School of Public Health's Division of Policy Translation and Leadership Development and the Harvard Kennedy School's Center for Public Leadership

- Cities of Desire (These are the sprawling slums and squatter communities. They are the favelas of Rio de Janeiro, the Dharavi section of Mumbai, and the outskirts of Shenzhen).

Barlow (Barlow, 2015) goes on to note that "*Smart city initiatives are not about technology … What makes a city unique is its culture and its people. The technology solution will need to support the systems and processes that allow that city to retain its uniqueness. Before a city begins a smart city initiative, its leaders need to identify the challenges the city faces. They must be ready and willing to look at the way its systems, services, policies, and procedures are working, or not working. The right technology solutions will focus on addressing the challenges defined by that city's unique nature.*"



On the other hand, Erol-Kantarci et al (Erol-Kantarci, Rehmani, & Mouftah, 2018) emphasize the use of technology to "*extract information from systems in the city to take measures for its management*", where with the use of next-generation information technologies, core systems (electrical grid, transportation systems, communication systems, water and waste systems, etc.) are sensed and "*bound together*", and the extracted information is analyzed for better management of the city and for improving quality of life in cities.

Infographics credit[4]

Prof Matthias Finger (Finger, 2019) points out that cities are "*socio-technical systems*", and any balanced view of the need for Smart Cities needs to consider the economic, sociological and technological aspects of each particular city for any Smart City initiative to be successful.

Finger (Finger, 2019) however goes on to describe a narrow framework for visualising a city as being a physical layer and a services layer, with the idea of a Smart City being to introduce a digital meta-layer between these two layers – to provide the interconnections required to achieve greater efficiencies, and at the same time provide a platform[5] for new services and innovation.

[4] https://www.bangalorean.com/blog/smart-city-project-phase-1-bengaluru/

[5] "*A platform is a business based on enabling value-creating interactions between external producers and consumers. The platform provides an open, participative infrastructure for these interactions and*

Finger's views are consistent with Erol-Kantarci et al's (Erol-Kantarci, Rehmani, & Mouftah, 2018) views, but whilst acknowledged by Finger he does not explicitly accommodate the views of Barlow (Barlow, 2015) in dealing with the important social aspects of cities.

Several authors and organisations emphasize (in our view correctly) the importance of "*multi-sided*" (Evans, 2016) or "*platform*" (Parker, 2016) (Rochet & Tirole, 2003) businesses, which inherently are more socially-inclusive than traditional "*pipeline*" businesses (especially when they are deployed on transparent trusted platforms like the blockchain), and are therefore more likely to be accepted and promote innovation - a key consideration for growth and development.

BLOCKCHAIN USAGE AND IMPLEMENTATION IN SMART CITIES

Blockchain goes hand in hand with the idea of a Smart Cities. Decentralised Ledger Technology (DLT) helps to transmit data securely and in a transparent way so therefore it is a relevant tool to fight corruption and make processes more efficient.

Here are a few examples of the potential of blockchain implementation in a Smart City (Yu, 2019):

- Decentralisation: the Blockchain systems run normally in a peer-to-peer manner without a centralised third party;
- Pseudonymity: in the Blockchain system, each node is linked to a public pseudonymous address, keeping its real-world identity hidden. The inherent pseudonymity is suitable for use cases where the users' identities must be kept private;
- Transparency: Blockchain technology enables everyone to access all transaction records which makes it transparent;
- Democracy: consensus algorithms are executed by all decentralised nodes to reach an agreement before a block is included into the blockchain. Thus, in the Blockchain system, decisions are made by all nodes in a peer-to-peer manner, which makes it democratised;
- Security: in the Blockchain-based decentralised systems, it is difficult to have a single-point of failure. Thus, the network security is enhanced;

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sets governance conditions for them. The platform's overarching purpose: to consummate matches among users and facilitate the exchange of goods, services, or social currency, thereby enabling value creation for all participants." (Parker, 2016).

- Immutability: in the Blockchain system, all transactions are signed using digital signatures. Moreover, the data blocks are linked and secured through the one-way cryptographic hash functions. Any small modification generates a different hash and can be detected immediately, which makes the shared ledger immutable.

Due to these good features, applying blockchain technology to Smart Cities can ensure data integrity, encourage organizations (e.g., companies, schools, hospitals, universities, local and national government) and individuals to share data and perform joint decision-making, enable transparent city management, and promote the implementation and deployment of a trusted, secure, transparent and democratized Smart City.[6]
We live in the age of Big Data, and more and more data gets collected. Therefore, it needs to be one of the key targets to protect data from any sort of hacks and fraud. Considering that especially sensitive data will be stored on huge servers these could be a target for hackers. In this case an alternative is provided.

It is estimated that 30% of care applications in Smart Cities, including medical care, are expected to have robotics and smart machines introduced into nursing operations by 2030. This introduction of some of our most sensitive data into the Internet of Things is one of the primary aims of Smart Cities, which means that securing that data is of the utmost importance.[7] This proves the importance of DLT to secure data from third parties.
Possible use cases for Smart Cities which require blockchain technology related to its sensitiveness of data would be for example:

- Universal identification cards;
- Land and property management;
- Interoperability for smart devices;
- Security for all sort of IoT Devices;
- Keyless signature interfaces (e.g. eye scan/ thumb scan);
- Universal Cloud Storage Platforms.

[6] Yu, F. R. (2019). Blockchain Technology and Applications - From Theory to Practice. Kindle.
[7] https://www.disruptordaily.com/blockchain-use-cases-smart-cities/

Many studies have been conducted about how technology (IoT, Blockchain, Big Data, mobility…) can deliver a better quality of life.
According to a recent McKinsey report[8], the number of Smart Cities will reach 600 worldwide by 2020. Even more astonishingly, it is estimated that Smart Cities will contribute up to 60% of the world's GDP by 2025 and nearly 70% of the world's population will move to urban areas.

Many problems will arise such as pollution, pressure on water resources and social inequalities and we will have to think about new solutions to resolve these problems. Blockchain is leading to be the most appealing Smart City technology that has the potential to make cities' operations more efficient, secure, and transparent.

Applying Blockchain technology to future Smart Cities could be the key to solving a variety of socio-demographic problems.

The primary driver behind adopting Blockchain technology for the government sector is its aim to support an open, transparent, and collaborative government that can streamline access to public services and contract management[9].

Below are some use cases where Blockchain technology can have major impacts on Smart Cities:

- Crime Prevention: crimes involving forgery and counterfeiting maybe prevented from alteration through the use of Distributed Ledger Technology (DLT);

[8] https://www.mckinsey.com/industries/capital-projects-and-infrastructure/our-insights/smart-cities-digital-solutions-for-a-more-livable-future
[9] Blockchain Use Cases in Digital Sectors: A Review of the Literature, Conference paper July 2018, page 8

- Corporate: authorization of corporations to use electronic networks or databases for the creation or maintenance of corporate records, the use of a network addresses to identify a corporation's shareholder, corporations to accept shareholder votes if signed by a network signature that corresponds to a network address, specifying requirements for use of electronic networks or databases;
- Property: recording and maintaining the rights of ownership or use for sales, leases and documents of title. Classifying a signature, record or contract secured through Blockchain technology as an electronic form of signature or record respectively. Recognition of Smart Contracts in commerce and establishing a Smart Contract that will not be denied legal standing, validity or enforceability. Maintaining a person's rights of ownership or use of information prior to using innovative technologies to secure information for commerce;
- Construction: automating a construction project from commencement to completion. Standardizing construction and supply contracts for government projects. Automating payment for faster project completion, and the elimination of delay and payment disputes. Increasing the trust between all stakeholders in the project as a result of creating an insulated project ecosystem where payment is guaranteed, records are maintained and available to all parties, and project status is transparent to all stakeholders.

HOW CAN BLOCKCHAIN BOOST THE DEVELOPMENT OF SMART CITIES?

In quoting Smart City initiatives in the metropolitan areas of Santander, Antwerp, Abu Dhabi and Bologna Yu (Yu, 2019) points out a key ingredient that is key to success – the need for incentives for the owners and managers of Internet of Things (IoT) data, to give up this data for the greater good. Finger (Finger, 2019) also makes the telling statements: "*data is as good as who owns the data*", and "*all the data generation and the services are integrated, and there are the different companies that own these data* and offer the services [that] are competing against each other, not sharing this data". He goes on however to the paint a more positive vision; that "*there are data platforms and the different data generators feed all these data into the platforms, and then the services providers take the information from these platforms and develop different types of services to different types of customers as a result of that*". Finger does not espouse a solution for this data conundrum, but in our view the ability of Blockchain technology to provide a trusted incentivised platform for holding data holds the key to gaining multi-stakeholder participation in any Smart City initiative.

Yu (Yu, 2019) reinforces our view by noting that Blockchain has the inherent characteristics of decentralisation, pseudonymity, transparency, democracy, security and immutability and "*due to these good features, applying blockchain technology to smart cities can ensure data integrity, encourage organizations (e.g., companies, schools, hospitals, universities, local and national government) and individuals to share data and perform joint decision-making, enable transparent city management, and promote the implementation and deployment of a trusted, secure, transparent and democratized smart city*".

The digital meta-layer and connectedness referred to by Finger (Finger, 2019) and others will facilitate advancement through the development of advanced technologies like "machine learning, data science, AI [and] deep learning" and accelerate the city economy along the Machine Intelligence Continuum (Yao, 2019); from "*Systems that Act*", through "*Systems that Predict, Learn, Create, Relate and Evolve, all the way to Systems that Master*". (Yao, 2019)

Tapscott and Tapscott (Tapscott & Tapscott, 2018) in describing the "*Seven Principles of the Blockchain Economy*" reinforce the principles of implicit trust and alignment of incentives as being key features of a Blockchain economy, and Mougayar et al (Mougayar & Buterin, 2016) agrees with this by emphasizing the "*trust layer*" provided by Blockchain technology.

Which brings us to why Blockchain technology will, in our view, promote the development of Smart Cities. Blockchain technology, together with a well thought out incentivisation protocol, has the unique ability to encourage participation of all stakeholders in Smart Cities, including regulatory authorities, current service and infrastructure providers, developers and the public – and all of this will lead to unprecedented innovation.

In their seminal work Bessant et al (Bessant & Tidd, 2013) clearly set out the critical role that innovation plays in the development of any economy, and the quote below captures this well:

"*Why Innovation Matters - Whilst competitive advantage can come from size, or possession of assets, etc. the pattern is increasingly coming to favor those organizations that can mobilize knowledge and technological skills and experience to create novelty in their offerings (product/service) and the ways in which they create and deliver those offerings. Innovation matters, not only at the level of the individual enterprise but also increasingly as the wellspring for national economic growth. In a*

recent book Baumol pointed out that 'virtually all of the economic growth that has occurred since the eighteenth century is ultimately attributable to innovation'. The magazine Business Week regularly features its list of the top innovative firms in the world. It found that the median profit margin of the top 25 firms was 3.4% in the period 1995–2005 whereas the average for other firms in the S&P Global Index was only 0.4%. Similarly, the median annual stock return was 14.3% for the innovators and 11.3% for the rest."

The following quote by Steve Jobs probably sums up the potential of Blockchain best, if you replace "computer" with "Blockchain":

"*I read a study that measured the efficiency of locomotion for various species on the planet. The condor used the least energy to move a kilometer. Humans came in with a rather unimpressive showing about a third of the way down the list.... That didn't look so good, but then someone at Scientific American had the insight to test the efficiency of locomotion for a man on a bicycle and a man on a bicycle blew the condor away. That's what a computer* [Blockchain] *is to me: the computer* [Blockchain] *is the most remarkable tool that we've ever come up with. It's the equivalent of a bicycle for our minds.*"

INTO THE FUTURE AND BEYOND…

Without doubt some of the biggest issues in using private data for public purposes are that of privacy, and the need to ensure that data provided to any transparent Blockchain is from a trusted source and is secure. This is covered more fully below, but it is worth pointing out the significance of what Boye (Boye, 2019) says; that there are many issues associated with privacy and security, including that there is a trade-off between innovation and security, and risks such as "*a terrorist turning all the traffic lights of a city to green at the same time or selectively changing traffic lights and producing fake data to divert traffic to specific areas*". These are real issues and real risks and point to the need for a permissioned Blockchain – which means more centralisation, and possible loss of trust. This is the essential balance that needs to be struck. After all, we want to avoid situations described "*in Isaac Asimov's 1954 science fiction novel, The Caves of Steel, Earth's cities have metastasized into huge dome-covered labyrinths, providing food and shelter—but little else—for billions of miserable inhabitants.*" (Barlow, 2015), where the state ends up controlling all data on the Blockchain and all the inhabitants of Smart Cities!

USE CASES: DEPLOYING BLOCKCHAIN

One of the top researches in Blockchain deployment for Smart Cities was conducted by Boyd Cohen, dean of research at EADA Business School, Barcelona, and co-founder of IoMob and the Blockchain Cities Alliance.

The analysis is supported by eleven different data points in the categories that include Blockchain start-up activity, Blockchain leadership, regulatory friendliness and Smart City. This is the first-ever distinctive research analysis conducted to discover the top ten Blockchain cities of the world[10].
Singapore, London, Zug, New York, San Francisco, Berlin, Tallinn, Toronto, Dubai, Hong Kong are the top ten cities spotted as the leading Blockchain cities in the world. Many other countries are today also engaged in Smart City initiatives. We will focus in this part on four distinguished use cases where and how they are transforming to a framework for implementing a vision of advanced and modern urbanization.

Dubai

The UAE Blockchain Strategy 2021 was launched by the UAE Government in April 2018. The main aims of the strategy are to capitalise on the Blockchain technology and to develop government transactions on a federal level into using the Blockchain platform by 50% over the next 3 years. The outcomes of this will include saving time and resources for individual users as well as the UAE Government. His Highness Sheikh Mohammed bin Rashid Al Maktoum stated that, "*The adoption of this technology will reflect on the quality of life in the UAE and will enhance happiness levels for citizens*"[11].

By adopting this technology, the UAE government expects to save:

- AED 11 billion in transactions and documents processed routinely;
- 398 million printed documents annually;
- 77 million work hours annually[12];
- 1.6 billion kilometers spent driving11.

[10] https://www.smartcity.press/smart-city-blockchain-technology-2018/
[11] https://sheikhmohammed.ae/en-us/news/details?nid=25825&cid
[12] https://government.ae/en/about-the-uae/strategies-initiatives-and-awards/federal-governments-strategies-and-plans/emirates-blockchain-strategy-2021

Singapore

As per the research of Boyd Cohen, Singapore leads a ranking of the top ten Blockchain cities in the world.

By November 2014, Singapore Government launched "Smart Nation"[13] to deliver digital solutions and create a nation "*where we can create possibilities for ourselves beyond what we imagined possible.*"[14]

In concert with the "Smart Nation", the Government of Singapore then created "The Digital Government Blueprint" in 2018, and outlined a five-year roadmap for the government to "*harness digital technologies to transform how it serves the public.*" Singapore follows three key pillars: digital economy, digital government and digital society[15].

Smart Nation has the mission to drive transformation in[16]:

- Health: Singapore digital transformation by using Blockchain is projecting to deliver healthcare services efficiently. Singaporeans are already using wearable devices or smartphones to monitor their health and activities, and this data can empower individuals and inform service delivery;
- Education: the use of Blockchain in the educational sector will enhance the relationships between students, teachers and parents, as well as capabilities of the physical infrastructure are augmented to create a holistic and conducive environment for effective learning;
- Transport: data analytics, smart systems and autonomous vehicles are key solutions for the future of transport planning and operations. Our roads and transport system will be optimised, making traffic smoother, public transport more comfortable and reliable, and the air cleaner with less need for private cars;
- Finance: Singapore will continue to be a leading regional and global financial hub, powered by financial institutions that readily adopt fintech solutions for better customer service, greater efficiencies in trade finance, strengthened supervision and reduced compliance cost.

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[13] "*A Smart Nation is a Singapore where people will be more empowered to live meaningful and fulfilled lives, enabled seamlessly by technology, offering exciting opportunities for all.*", https://www.smartnation.sg/

[14] Smart Nation Strategy Nov2018, paper from https://www.smartnation.sg/

[15] https://theblockchainland.com/2019/03/05/blockchain-role-developing-smart-cities/

[16] Smart Nation Strategy Nov2018

Georgia

Georgia's National Agency of Public Registry (NAPR) moved its land registry into the Blockchain with the objective of allowing Georgian citizens to "*sleep quietly*" when it comes to property rights.[17]

The Republic of Georgia developed a product called "Exonum" to put their registry on the Bitcoin Blockchain. Georgia is using a private permissioned Blockchain to keep critical records and then using the public Bitcoin Blockchain to publish hashes of essential documents. By hashing a document - which is generating a unique short set of characters based on that data - and posting it into a field for extra data, one can use the public Bitcoin Blockchain as a notary.[18]

Estonia

Estonia has been testing Blockchain technology since 2008. Then Since 2012, Blockchain has been in production use in Estonia's data registries, such as the national health, judicial, legislative, security and commercial code systems, with plans to extend its use to other spheres such as personal medicine, cybersecurity and data embassies.[19]

The interesting point here is that Estonia has used Blockchain even before bitcoin was invented. The main reason is the cyberattack of 2007, when — at one point — the websites of state services and the government went offline because of heavy DDoS attacks. This caused Estonia to reconsider its attitude toward data security and reach out to what we are now calling Blockchain. [20]

Some of Estonia's Blockchain use cases are:

- X-Road[21] is rooted in a Blockchain called K.S.I., which was developed by Guardtime, one of the biggest Blockchain companies in the world. Today, it is implemented in Finland, Kyrgyzstan, Namibia, Faroe Islands, Iceland, Ukraine, and

[17] https://www.saisreview.org/2019/01/16/blockchain-for-governance/
[18] BLOCKCHAIN AND PROPERTY IN 2018: AT THE END OF THE BEGINNING, J. Michael Graglia, Christopher Mellon
[19] Estonian Blockchain technology, https://e-estonia.com
[20] https://www.investinblockchain.com/estonia-blockchain-model/
[21] X-Road is the backbone of e-Estonia. Invisible yet crucial, it allows the nation's various public and private sector e-service information systems to link up and function in harmony.

other countries. Two X-Road ecosystems can be joined together, federated. Federation is a one to one relationship between two ecosystems. Members of the federated ecosystems can publish and consume services with each other as if they were members of the same ecosystem. Federation enables easy and secure cross-border data exchange between these ecosystems. The federation between Estonia and Finland was established in February 2018;[22]

- E-land registry: The e-Land Register is a one-of-a-kind web application that contains information on all ownership relations and limited real rights for properties and land parcels. Currently, there are over 1 million immovables in the Land Register;
  Paired with a geographical information system (GIS), the electronic Land Register delivers real-time geographical data through the X-Road, enabling advanced map-based visualisations that power many of the location-based services in Estonia;
- E-identity: which contain four projects (ID-card, Mobile-ID, e-Residency and Smart-ID) and will get a look to only ID-card. Estonia has by far the most highly-developed national ID-card system in the world. Much more than a legal photo ID, the mandatory national card also provides digital access to all of Estonia's secure e-services. The chip on the card carries embedded files, and using 2048-bit public key encryption, it can be used as definitive proof of ID in an electronic environment;
- ID-card is used for[23]:

  i. legal travel ID for Estonian citizens travelling within the EU;
  ii. national health insurance card;
  iii. proof of identification when logging into bank accounts;
  iv. for digital signatures;
  v. for i-Voting;
  vi. to check medical records, submit tax claims, etc.;
  vii. to use e-Prescriptions.

DEEP DIVE USE CASE: SMART DUBAI

Taking a closer look into one of the most committed, sustained efforts from a government to create one of the first working Smart City ecosystems, we find the United Arab Emirates led by the Emirate of Dubai, positioning themselves arguably as global leader and trendsetter. The government is proposing favorable initiatives,

[22] https://e-estonia.com/solutions/interoperability-services/x-road/
[23] https://e-estonia.com/solutions/

regulations and support towards both its public and private sector, incentivising them towards building together the world's first Smart City with an emphasis on the enablement of Distributed Ledger Technology and Blockchain.

The United Arab Emirates and especially Dubai, this melting pot bridging together Europe and Asia from the Middle East, has been widely regarded as a tolerant, safe tax haven that is home to many high net worth individuals and renowned international corporations. Although young in international relevance, it has been developing at an astonishing rate via state driven policies that have unilaterally grown the economy and local industry and displayed a large appetite for the innovative, novel, disruptive technological breakthroughs.

Blockchain and Distributed Ledger Technologies have turned many countries reluctant or passive in taking a firm position on the nuances that come with it but the UAE has keenly identified the promises it offers towards a wide array of applications and decided to nurse progress in the field through the adoption of unique programs.

Smart Dubai Strategy

The driving force behind the vision of H.H. Sheikh Mohammed Bin Rashid Al Maktoum is to make Dubai the happiest city on earth, and it is split across key pillars[24]:

- AI Lab: Dubai's first Artificial Intelligence Smart Lab under IBM partnership is providing the essential tools and go-to-market support for public and governmental entities;
- AI principles and ethics: Dubai's Ethical AI Toolkit is thought out to support individuals in navigating across the digital city ecosystem;
- Paperless: Dubai government will focus on implementing the necessary technology to enable paper-free transactions by 2021 and create a legal framework to address fully digital procedures;
- Smart Cities Global Network: Bringing together the best minds in the business into collaborating with the goal of driving development and knowledge transfer;
- Start-up support: With the support of UAE government institutions there have been initiated multiple cohort programs, accelerators and challenges to support small and medium enterprises (SMEs) in building products aligned with the

[24] https://www.smartdubai.ae/

program values. Multiple billion Dirhams (AED)[25] were promised and distributed to the teams qualified to the final phases of the competitions:

i. Global Blockchain challenge;
ii. Dubai Smart City Accelerator;
iii. Smart Dubai Office Accelerator;
iv. Mohamed bin Rashid innovation fund.

Blockchain - The Dubai Blockchain Strategy is destined to continually explore and evaluate the newest innovations in the DLT space that demonstrate an opportunity to deliver on the Strategy's purpose and enhance digital Smart City experiences, security and efficiency, including:

- Happiness Agenda: the transformation of Dubai through smart technology and innovation holds happiness as a primary goal;
- Emirates Blockchain Strategy 202: in April 2018, the UAE Government launched a similar initiative applicable on a national scale. The strategy aims to capitalise on the Blockchain technology to transform 50 per cent of government transactions into the Blockchain platform by 2021. It is expected to save 398 million printed documents and 77 million work hours annually;[26]
- The Global Blockchain Council – in 2016 through the Dubai Future Foundation, a committee for the exploration of Smart City Blockchain applications was formed, with a 46-member council of PUBLIC AND PRIVATE PARTNERS alike, including government entities, international companies, banks, free zones, and international Blockchain technology firms, such as: Microsoft, SAP, IBM, Cisco, Kraken, BitOasis, etc.[27]

The Dubai Blockchain Strategy, launched in 2016, was thought out to create a distributed database that is supporting smart contracts, sharing cryptographically secure citizen information enabling data validation and faster processing times in fields such as Identity management, Health & Medical, transport, Justice, energy, Supply chain, etc.[28] The Blockchain strategy targets three main domains of value creation[29]:

[25] https://gulfnews.com/technology/fin-tech/uae-accelerator-targets-about-30-entrepreneurs-in-first-year-1.60989300

[26] https://government.ae/en/about-the-uae/strategies-initiatives-and-awards/federal-governments-strategies-and-plans/emirates-blockchain-strategy-2021

[27] https://www.dubaifuture.gov.ae/our-initiatives/global-blockchain-council/

[28] https://scgn.smartdubai.ae/pdf/dubai-blockchain-strategy.pdf

[29] https://scgn.smartdubai.ae/pdf/blockchain-case-study.pdf

- Government Efficiency: the ''Everything on the Blockchain'' concept will facilitate the interoperability of governmental bodies, offering a digital one stop shop that can cater for any citizen needs;
- Industry Creation: since Blockchain shows disruptive promise across the entire economy, digital plug and play will be applied to enhance the industry status-quo or build new industrial use-cases al together;
- Local and International Thought Leadership: with the cumulated expertise building in house DLT solutions, Dubai is primed to become the hub for Blockchain intellectual capital and skill development thus offering a derived additional revenue stream for the local economy.

While the Abu Dhabi Global Markets and Dubai International Financial Centre, the two financial free zones established pursuant to the UAE Constitution and federal law, have already enrolled Blockchain specific regulations and guidelines for the investors, potential start-ups and established player entering Blockchain.[30]

The favorable regulatory and taxation parameters along with the business support functions are some of the main reasons why UAE ranks 2nd in STO token sales in Q1 2019 with ~$220M in raised capital for the projects operating in & from UAE. Dubai has been having an ever-growing influence in the global Blockchain ecosystem, attracting many investment companies to set roots locally.

The main drivers of the increased STO sale inside UAE is GCBIB, Genesisx Consortium Backbone Inter Banknet Alliance, raising ~$142M for developing banking and insurance products for UAE's token economy & Bolton Coin raising $67M, promising to offer a way to invest in various asset classes that feature crypto and real estate.[31]

Some other key Blockchain solutions rolled out in the UAE include:

- Payment reconciliation and settlement system that allows transaction to be performed accurately and in real time;
- Blockchain enabled bank check settlement;

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[30] https://thelawreviews.co.uk/edition/the-virtual-currency-regulation-review-edition-1/1176671/united-arab-emirates

[31] https://www.zawya.com/mena/en/press-releases/story/UAE_ranks_second_in_global_token_sales__leading_the_world_towards_a_digital_future-ZAWYA20190611033610/

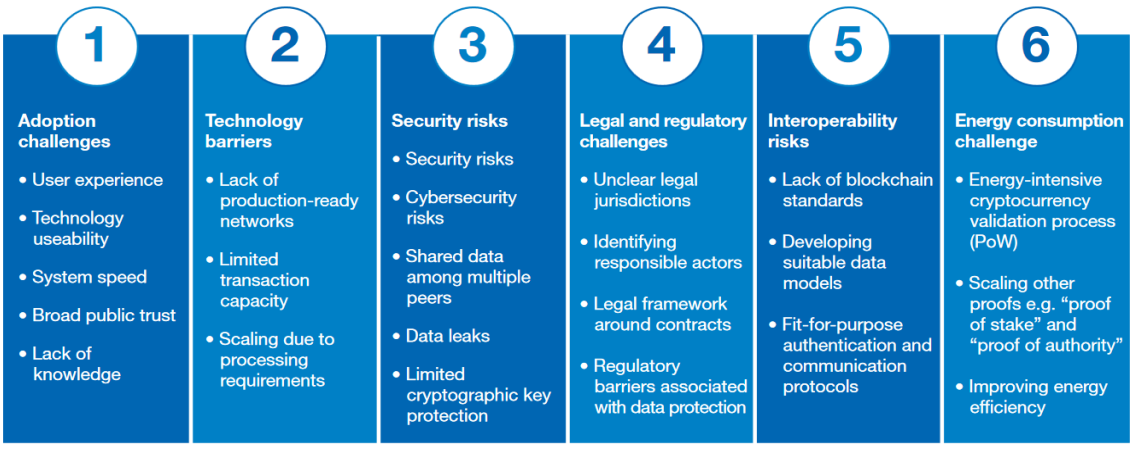
- Preliminary work to explore activation of cross-border enforcement of legal judgments through the Blockchain future research to focus on building dispute resolution mechanisms;
- A shared digital currency for cross-border bank transactions that could revolutionise the remittance industry and build investor faith in cryptocurrencies, was piloted by the central banks of the UAE and Saudi Arabia.

All in all, it appears that UAE have understood the huge growth potential that comes with being an early adopter and trendsetter of a disruptive technological advancement such as Blockchain and all the innovative use cases spanning across industries that come with it. The unblemished vision to stay at the forefront of defining guidelines while facilitating knowledge transfer represents encouraging reasons to believe that the state will be a pioneer in successfully digitising their economy while attracting more and more foreign entities to come operate within the country borders.

BLOCKCHAIN IMPLEMENTATION CHALLENGES IN SMART CITIES

As exciting as this new emerging technology is, Blockchain still has some limitations which are being thoroughly studied from researchers in the hope to find alternative solutions to its design flaws. As mentioned in one of PWC's reports (Blockchains for a better Planet, September 2018)[32] and illustrated in the picture the main limitations of the technology as of today are listed below:

High-level summary of blockchain risks and challenges



Source: PwC

[32] https://www.pwc.com/gx/en/services/sustainability/building-blockchains-for-the-earth.html

Who uses Blockchain?

When we refer to global or even on a metropole city scale issues, the first thought is that of effective scalability. Many of the current applications are much too complicated for them to foster adoption on a Smart City scale. TRUST is one of main ingredients of the "Blockchain stew'' and yet people need to trust the technology in order to adopt it. The user interface is crucial, the Internet didn't get adopted only by programmers; developers and its code is only a backend feature. The front end needs to be a simple to use interface. Users seek experiences and Blockchain does not yet abide by the simplicity rule.

Amazing Technology, not so easy to deploy.

Even though Blockchain has gained attention quickly from all kinds of industry due to its features, the technology is definitely not easy to deploy considering a lot of Blockchain projects worldwide have not been able to deliver the promise of a product.

Speed of transactions in public Blockchains has constantly given rise to debates and controversaries. Security over Speed? Which one can citizens of a city opt for? Now imagine a Smart City that runs its energy grid on the Blockchain? How many transactions would it need to perform? The answer is millions per second, which today is still unimaginable.

Blockchains operate on networks therefore the network of a Smart City would be constrained as the size of the network is limited due to its scalability issues.

Security is at risk

As the comedian James Veitch said in many of his funny "*spamming emails*'' stories online[33], true to an extent: "*The Internet gave us access to everything; but it also gave everything access to us*''.
Therefore, cybersecurity has become an increasing challenge even in the cryptocurrencies industry where the more centralised you are, the more hackable you become, in this case exchanges have lost millions in cyberattacks from malicious parties. Blockchains are designed to be secure from the underlying features of the technology itself but when we talk about security we must definitely tackle the privacy part. Private Blockchains maybe don't deliver the higher promise of public ones in a

[33] https://kzplayer.info/show/RGNleXkwY1g2SjQ.html

city environment but at least they protect enterprises from privacy issues related to data and of course the strength of the network itself in Blockchain lies in cryptography. Another pressing matter that threatens Blockchains is quantum computing[34]. Computers of today don't have the ability to solve immediately the mathematical computing problem that Proof-of-Work brings to the table. They have to compare all possible results and perform considerate computing exercises to find the right one, making Proof-of-Work let's say a time-consuming task that maintains the "*honesty feature*'' of the nodes in the network. Therefore, a quantum computer, which has the ability to be exponentially faster than a classical computer, and because of its massive computational power could, in theory, break today's public key cryptography, is considered nowadays a threat to Blockchains and to the value they represent in terms of security.

Legal & Regulatory landscape

Why are we not using Smart Contracts on the legal infrastructure of a Smart City? It's very easy, it's because they are not legally enforceable. Even Ricardian contracts are subject to jurisdictional difficulties. Although the technology is more than ten years old now, regulatory hurdles are its major obstacle. An emerging technology like Blockchain with limitless uses and applications cannot simply be regulated from the same 100 year old regulations. Regulatory authorities need more perspective in regulating certain aspects of the Blockchain.

Certain other issues are of course a big question mark and they stand above any state/city legal enforcements. How do you regulate a decentralisation concept? You can't simply force it, the legal infrastructure of today is not compatible with such a remarkable concept, but in order to avoid chaos we can refer to self-regulation instead. Regulatory authorities certainly don't have an easy task, considering that the distributed part of a Blockchain makes it hard to determine the jurisdiction under which the technology should be regulated, which laws should be applied, which legal bodies are responsible to resolve disputes and other pressing matters related to the very nature of Blockchain, such as data privacy issues, accountability issues and many more.

[34] https://medium.com/fintech-kellogg/quantum-computing-is-it-the-end-of-the-blockchain-10fa7e222b0av

Interoperability, a dream of many Blockchains

It all started with the original Blockchain that Bitcoin as a cryptocurrency presented to the world. As Nakamoto states in his original whitepaper "*Bitcoin: A P2P electronic cash system*'' [35]the show star was Bitcoin but the technology behind it was certainly noticed too and if you search Google today for the word Blockchain there's certainly a lot more than just the Bitcoin Blockchain. There are many more Blockchain protocols that have emerged with time and still a standard is not yet defined. The question remains if different cities are using different Blockchains or even inside the same Smart City you have different Blockchain protocols used, how are they supposed to communicate with each other easily without technical hurdles?

Can we afford Blockchain?

When we think of public Blockchains, that certainly use a considerable amount of electricity for the computational power that Proof-of-Work needs as a consensus mechanism, it's natural to also think: If a public blockchain with Proof-of-Work is used, can a Smart City, that is actually aiming at reducing costs, afford that kind of electricity consumption? An unanswered question yet and rather a disturbing environmental challenge.

IGNORING THE OBVIOUS! WHAT CAN A FUTURE BLOCKCHAIN-BASED SMART CITY LOOK LIKE?

However, if we take for granted that the efforts and struggles of the present time, hopefully in the near future, get rewarded and the above issues have been overcome or solved in other ways, then it's quite easy to have a clear picture of what this technology could offer to the citizens of a Smart City and how it can change but at the same time connect entire economies worldwide.

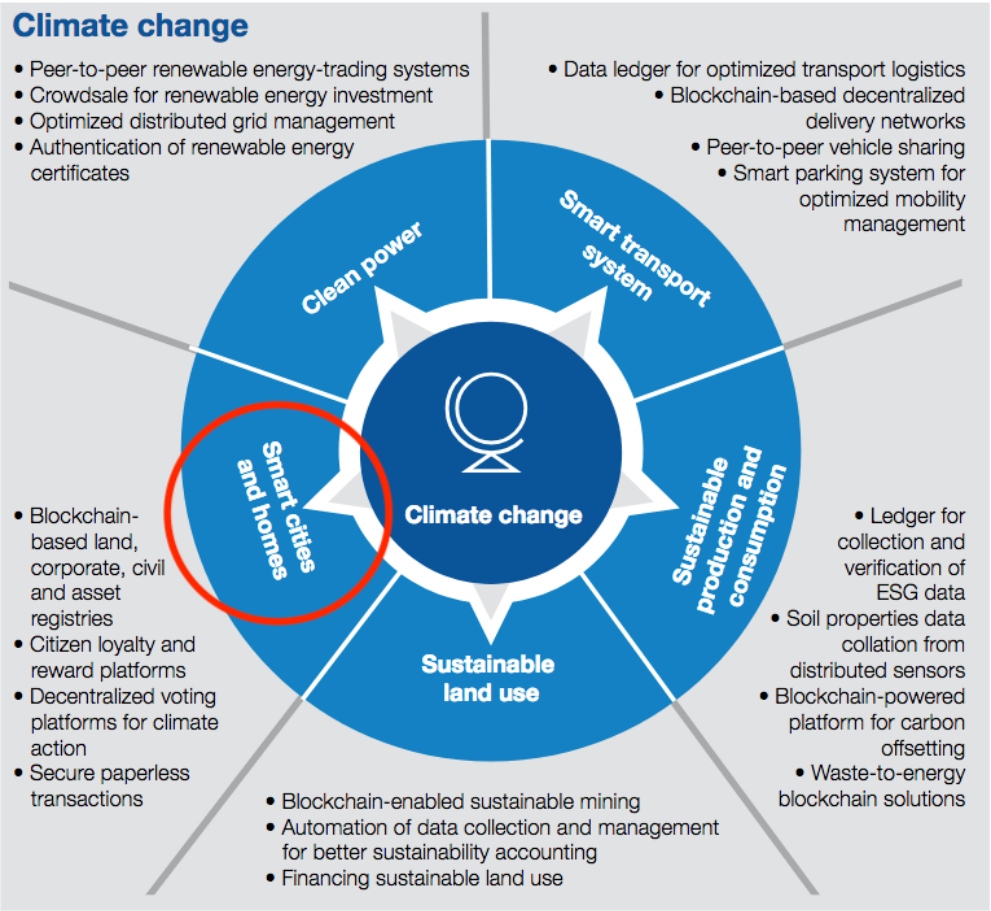
Decentralised Smart City energy grid & P2P trading

Decentralised energy grids would be a perfect example of cutting costs and increasing energy efficiency by also supporting renewable energy. Assuming that coordination

[35] https://bitcoin.org/bitcoin.pdf

issues across all these grids are solved, in the perfect case scenario we could use smart contracts to optimize this coordination enabling energy trading in the local markets but also inter-city trading.
Combining blockchain technology and Smart Contracts with smart meter technology will allow for easier traceability of energy resources. This enables efficient P2P trading which is a very innovative phenomenon already being piloted as a Proof-of-Concept in Bangkok, Thailand.[36]

Imagine a city where local energy resilience through rerouting power for example in cases of natural disasters or in areas where is most needed (energy scarcity) is easy once you remove from the picture the technological and regulatory hurdles. Enabling such a futuristic approach there wouldn't be much need for energy companies, energy traders and all the other 3rd party providers and further more energy transportation losses would be considerably removed. All transactions are recorded on the blockchain building trust and transparency in the citizens of a Smart City.



[36] https://medium.com/power-ledger/case-study-learn-more-about-our-live-project-with-bcpg-in-bangkok-thailand-ab7a31c8b464

Infographics Source: World Economic Forum

Decentralised Water Management

As clearly stated even by the World Economic Forum,[37] blockchain could in the future be the solution to a fully decentralised water management. When combined with other technologies of the 4th Industrial Revolution technologies, blockchain could optimize water management, offer at the same time real-time transparent data on water quality and quantity, can give information on conservation, dynamic pricing and trading, and spot water tampering. As in the decentralised energy grids, P2P trading could be possible also for water resources allowing water users willing to share their excess resources to become "prosumers" without relying on a centralised authority and the next stage of deployment would include blockchain with IoT and machine-learning (ML) to create a fully decentralised water management system where local resources and water-recycling would add value and truly improve citizens lives.

Interconnected Smart Cities worldwide

Blockchain and Smart Cities concepts are each destined to shape our future in different ways, but they could shape it by working together. Scientists and different research teams have described future urban developments to be more interconnected than ever before.[38]

The future cities that we will live in will be more interconnected than ever. IoT devices and sensors will help transmit data, create efficiencies and adapt our living habits to our environment.
Incorporating blockchain into the development of Smart Cities will make it possible to have a cross-cutting platform that connects the cities' different services, adding greater transparency and security to all services and processes.

Blockchain is not unique because it works alone but because it can cooperate perfectly with other technologies such as AI, ML, IoT that are considered key elements of the 4th Industrial revolution [39]. Imagine a city interconnected in all ways and imagine entire

[37] http://www3.weforum.org/docs/WEF_Building-Blockchains.pdf
[38] https://medium.com/wolverineblockchain/the-radical-and-interconnected-future-of-blockchain-and-smart-cities-59573c26f2e1
[39] https://interestingengineering.com/the-technologies-building-the-smart-cities-of-the-future

Smart Cities interconnected with each other, transferring data, sharing secure information and P2P resources trading, from one Smart City to another.

A Smart City incentivising token economy

Today crowdfunding is not news anymore but for the past years we have seen multiple stages of the process, ICOs, IEOs, STOs and a lot of projects focusing on the technology but not many of them trying to bring a change to environmental issues that would impact the lives of citizens in a city. What about using in the future this newly financing method, to fund a Smart City's tenders or green projects? A so called "*Token Economy*'' by itself is still at infant stages but the possibility to finance projects and practices that have a positive environmental benefit will certainly flourish in the future. Crypto-tokens driven by population incentivisation will be certainly a game changer in behavioral science studies. This use case extends beyond just changing behavior and could also incentivize companies to design and manufacture products in ways that make it easier to manage the product lifecycle and to re-harvest materials. Citizens could be incentivised too through circular economies and earn while they perform good deeds that benefit anyone. Smart citizens in a Smart City, the perfect combination!

Humanity is saved

Still very far from real world implementation but blockchain technology is beginning to be seen by scientists as a way to improve disaster preparedness and relief effectiveness.
For example, according to World Economic Forum report[40]: "*connecting suppliers of clean drinking water with the helicopter pilots delivering that water could help ensure that deliveries during a natural disaster phenomenon are scheduled at specific locations within certain time frames. To enable this solution, smart-contract technology can determine which contract offer is the best one available based on the delivery needs of the community, including quantity, price, timing and location. The smart contract can trigger acceptance of the offer, and set in motion the delivery as well as confirming the delivery has taken place. An important challenge here will be to integrate disaster preparedness and relief platforms into existing early- warning and mobilisation systems, across both public and private entities. Ensuring adequate trust and resolving intellectual property (IP) and data privacy issues will be particularly*

[40] http://www3.weforum.org/docs/WEF_Building-Blockchains.pdf

important. Further challenges might arise in developing countries where IT systems might not yet be Fourth Industrial Revolution-compatible without significant investment and upgrades''.

A futuristic legal autonomous system

Smart Contracts have the power to transform the complete legal system in a Smart City, after all the keyword here is always "*smart*''. Regarding this point we took some valuable thoughts from an interview with Karm legal Consultants[41], a firm based out of Dubai specialising in emerging technologies. We asked the CEO Kokila Alagh what was her input about the legality and incorporation of Smart Contracts in the legal system of a Smart City, below her thoughts:

"*Smart Contract as such 'is a computer protocol intended to digitally facilitate, verify or enforce the negotiation or performance of a contract using blockchain technology.' Theoretically, Smart Contracts may be used to create or enter into a legal contract between the parties or performing/executing certain parts of the contract. Further, laws in various jurisdictions, have made it possible to enforce a contract concluded or performed, wholly or partly, through electronic means or records, where these activities or records are not subject to any follow-up or revision by a natural person. UNCITRAL Model Law on Electronic Commerce (1996) is the international legislation which recognizes the possibilities of various modes of transacting, including by way of electronic means. There are many jurisdictions around the globe that had have recognized the possibility of digitized and automated modes of transacting like that by way of smart contracts. For example, in the UAE the Federal Law No. (1) of 2006 on Electronic Commerce and Transactions, gives such contracts formed without intervention of natural persons legal validity. As per Article 12 of the law, a contract may be formed by the interaction of Automated Electronic Agents that include two or more electronic information systems preset and preprogrammed to carry out these tasks. Such contract would be valid and enforceable even if no individual was directly involved in the conclusion of the contract within such systems. Further, a contract may be formed between an automated electronic information system in the possession of a natural or legal person and another natural person, where the latter knows or has reason to know that the such a system will automatically conclude or perform the contract. Therefore, barring certain exceptions, the smart contracts are a valid form of contracting in UAE.*

[41] www.karmadv.com

Having said that, the ability of such smart contracts to function efficiently depends on the technical robustness of all aspects of an economy. The legality and adoption of smart contracts is heavily dependent upon the interconnection of community with both private stakeholders and the government. Applying smart contracts to isolated services in public and private sector may be an easy feat, however, the dynamics significantly change when the same is to be used in a governance model, like that in the case of smart cities. One of the simplest examples of incorporation of smart contracts can be that of incorporation into the commercial supply chain of goods in the city. For the supply-chain based on the blockchain and smart contracts to function efficiently, it is essential for not only the players in the distribution network but also the governmental authorities overlooking customs and consumer protection to be on board to verify the validity of such commercial transactions''

As Robert Hernian states in his publication [42] summary about legal recognition of blockchain and smart contracts: "*Generally-speaking it is correct to assume that technology does not break laws, breach contracts or contravene rights, people do. This means lawmakers must remain in-step with conduct produced by technologies such as blockchains and not allow legal recognition to lag behind.*''

There are multiple countries right now that are considering smart contracts to have a legally binding contractual effect. Regarding current applications of smart contracts into a Smart City or Smart Nation and the future vision of enhancements of the technology Akshata Namjoshi, Associate at Karm Legal Consultants states that "*So far, there have been many examples of use of blockchain at federal and state levels around the world. Estonia for instance is one of the first few nations that has devised national electronic health record system in order to create an easily accessible record which can be accessed by every patient online. This is a centralized national data set which runs on KSI Blockchain Technology in order to ensure privacy and data security from threats. Similarly, City of Zug in Switzerland conducted its first blockchain based electronic voting test from 25 June to 1 July 2018. 72 identity card holders participated in the consultative process.*

As such keeping in view the aim of Smart Cities, smart contracts can be used for digitizing identification, voting, tax, track ownership of assets, payment systems and automating bureaucratic processes. This is likely to boost the sustainability in the economy and help the widescale adoption of blockchain and other frontier

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42 https://www.researchgate.net/publication/329715394_Legal_Recognition_of_Blockchain_Registries_and_Smart_Contracts

technologies. The other potential use cases of smart contracts and blockchain could be in the aspects related to waste management, environmental issues, education and telecommunication in case of Smart Cities. But we would need to remember that, any new technology needs time to grow and become sustainable. Smart Contracts are the facet of technology which have made transacting easier. Whether or not they will replace conventional modes of contracting is a different debate altogether, however, mass adoption of smart contracts is likely to help the development and vision of Smart Cities. The adoption will be fully successful only when all the players on the spectrum are on board- right from the community to the federal players''

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