DISCUSSION PAPER

BLOCKCHAIN FOR URBAN DEVELOPMENT

Guidance for Urban Managers

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UN-Habitat Innovation Unit
External Relations, Strategy, Knowledge and Innovation Branch

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FOR A BETTER URBAN FUTURE

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BLOCKCHAIN FOR URBAN DEVELOPMENT

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Contents

Introduction

Rapid urbanization and technological advancements are among the megatrends reshaping the world.[1] Today, more than half of the world population lives in urban areas, compared to roughly 30% in 1950. It is projected that two-thirds of the world population will reside in urban areas by 2050.[2] These projections have significant sustainability implications as much of the world's economic, social, and cultural activities are concentrated in urban areas. On the other hand, rapid improvements in connectivity, internet penetration and speed, and new technologies (such as cloud computing), are accelerating digitization and making frontier technologies more efficient. These technological breakthroughs are changing how society lives, does business and governs itself. In addition, they are becoming increasingly critical in addressing long-standing issues related to urban development such as limited tenure security, livelihood generation activities, and access to basic services.

Blockchain is one of the relatively new and rapidly developing technologies that could assist in accelerating the achievement of the 2030 Sustainable Development Goals.[3] While blockchain has been applied somewhat successfully in the financial sector, its applications are now being sought in areas such as land management, energy management, and governance. UN System organizations are experimenting with the technology and piloting its use in the areas of "supply chain, digital payments, tracing of livestock, digital identity and land registration".[4] Policies, standards and close examination of the legal aspects of blockchain use are deemed critical in reducing the legal uncertainty and henceforth accelerating the adoption of blockchain in the UN System.

This paper, by UN-Habitat, discusses blockchain's unique features in relation to urban development. Specifically, the paper explores potential applications of blockchain in addressing challenges related to sustainable urbanization as well as the risks and challenges associated with its implementation. The paper targets city leaders, managers and policymakers who may be interested in adopting blockchain technologies in the provision of services, as well as other stakeholders such as the private sector, donors, civil society, and UN agencies. The main objective of the paper is to critically discuss the potential of, and concerns about blockchain through an urban looking glass. It aims to expand discussion on potential applications of blockchain to include sustainable urban development.

A key argument of this paper is that, like many technologies, blockchain itself is not a panacea for addressing sustainability challenges in urban areas and must be adopted whilst integrating human-centered approaches and robust business processes. It must also consider adequacy of capacity including financial resources, human resources, local culture, infrastructure, and governance systems, while minimizing exacerbation of inequality in access and benefits.

The paper is comprised of eight sections. Section one provides the general orientation of the paper. Section two introduces blockchain technology, briefly describing how it works and the distinct types of blockchain. Section three briefly describes the usage of blockchain by United Nations agencies. Section four discusses the potential applications of blockchain technology for urban management. This section also provides several case studies of cities implementing blockchain. The fifth section discusses the risks and concerns associated with implementation of blockchain. Section six analyses the preconditions necessary for successful implementation of blockchain in cities. In sections seven and eight, the paper provides a set of recommendations to guide urban managers in cities seeking to adopt this technology.

1 https://www.pwc.co.uk/issues/megatrends.html
2 https://population.un.org/wup/Publications/Files/WUP2018-Report.pdf
3 https://www.un.org/en/newtechnologies/
4 https://www.unjiu.org/sites/www.unjiu.org/files/jiu_rep_2020_7_english.pdf


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CHAPTER 01

What is Blockchain?

The concept of blockchain was introduced in a white paper by "Satoshi Nakamoto"[5] in 2008 as the underlying technology for bitcoin, "[a] peer-to-peer version of electronic cash that would allow online payments to be sent directly from one party to another without going through a financial institution."[6] To address the commonly known "double spending" problem – the risk that a digital currency can be spent twice[7] – the paper proposed a system where "[t]he network timestamps transactions by hashing them into an ongoing chain of hash-based proof-of-work, forming a record that cannot be changed without redoing the proof-of-work."[8] While Bitcoin was the first use of blockchain, it is only one application of how the technology can be used to store information.

Since this initial paper, blockchain has developed to be understood as "a distributed append-only time stamped data structure"[9] that keeps records of transactions in the form of »block" of information, connected in a chain-like format, that can be shared securely across computers on a shared network. Put another way, blockchain is a shared digital database that can be used simultaneously by everyone on the network (peers or participants) and all computers in the network can view and retain a copy of all records. The "peers" or stakeholders in the blockchain network agree among themselves to any changes made to the shared database without the intervention of a third party.

Although blockchain is similar to other database technologies in the way it stores information, it has attributes that make it unique and preferred in many of its applications.

First, even though the system is not "hack-proof", blockchain systems are considered to be less vulnerable[10] (at least as compared to other databases) in many contexts. Most transactions take place across an interlinked peer-to-peer network, and records are replicated completely or partially across several interconnected systems. Communication between parties is also secured through cryptography and any information intercepted is usually not comprehensible.

Second, it is impossible to change records (immutability) as every 'block' with a record is uniquely connected via a digital signature to another 'block'. The entire history of a record is available over a blockchain and once a transaction is completed, it can never be reverted.

Third, (and in an ideal state), there is no need for a centralized third party or owner as information is transferred across the internet once all parties agree to a network verified transaction. Transactions are verified by a pre-determined set of rules. In addition, this removes the need for reconciliations hence allowing for automatic execution of agreed actions once predetermined conditions are met.

The attributes described above enable blockchains to perform three main functions:

1. store information,
2. track the exchange of value, and
3. digitize and automate rules through smart contracts (programs stored on blockchain that run when predetermined conditions are met).[11]

5 Satoshi Nakamoto is presumed to be a pseudonym, and no person named Satoshi Nakamoto has come forward or claimed ownership.
6 Satoshi Nakamoto, "Bitcoin: A Peer-to-Peer Electronic Cash System," October 31, 2008. Available at: https://bitcoin.org/ bitcoin.pdf
7 https://www.investopedia.com/terms/d/doublespending.asp
8 Satoshi Nakamoto, "Bitcoin: A Peer-to-Peer Electronic Cash System," October 31, 2008. Available at: https://bitcoin.org/ bitcoin.pdf
9 http://www.sciencedirect.com/science/article/pii/S0736585318306324
10 http://ficci.in/spdocument/22934/Blockchain.pdf
11 https://atrium.uninnovation.network/guide

Blockchain's unique features and functionalities can be leveraged to meet the need for complete, secure, authentic and trustworthy information exchange across various fields[12] and to promote transparency, efficiency and good data management practices which are basic building blocks for urban development solutions. For example, it can be used to make city management processes more secure, transparent, efficient and resilient. This may induce indirect positive effects in city management and productivity, such as in the streamlining of procurement, operational, and service-delivery processes.[13]

At the same time, it is worth noting that the technology is also considered to have some inherent limitations, partly because of the dynamic and fluid contexts in which it has to operate. Blockchain alone, for example, "is not a magic solution and information must be organized and digitized for blockchain to work". It does not exist outside a political, governance, cultural and social system, and the resources in place to manage such a system which can affect its ultimate operationalization. In some contexts, there is a shortage of expertise and technical skills to implement blockchain-based solutions, especially in developing and less developed countries. The pros and cons of blockchain are discussed later in the paper but the key message at this point is that the adoption of blockchain "should be approached with an open mind and a healthy dose of skepticism"[14]. Practitioners need to determine whether blockchain technology is the right fit for a particular problem, or whether an alternative tool may be more appropriate.

12 http://ficci.in/spdocument/22934/Blockchain.pdf
13 http://ficci.in/spdocument/22934/Blockchain.pdf
14 https://icma.org/articles/article/icma-releases-whitepaper-blockchain-technology-and-its-application-local-government

1.1. Different Types of Blockchain

There are four main types of blockchain based on the level of "openness of the platform (public or private) and the level of permissions required to add information to the blockchain (permissioned or permission-less)."[15]

Public blockchains can be viewed by anyone, while private blockchains are only open to a select group of people. On the other hand, permissioned[16] blockchains only allows authorized users to transact (commit and record transaction), while permission-less[17] blockchains permits anyone to do so.

Table 1: Main types of Blockchains segmented by permission model[18]

			READ	WRITE	COMMIT	EXAMPLE
BLOCKCHAIN TYPES	OPEN	Public 'permission-less'	Open to Anyone	Anyone	Anyone	Bitcoin, Ethereum
		Public permissioned	Open to anyone	Authorized participants	All or subset of authorized participants	Supply chain ledger for retail brand viewable by public
	CLOSED	Consortium	Restricted to an authorized set of participants	Authorized participants	All or subset of authorized participants	Multiple banks operating a shared ledger
		Private permissioned "enterprise"	Fully private or restricted to a limited set of authorized nodes	Network operator only	Network operator only	External bank ledger shared between parent company and subsidiaries

Source: Hileman & Rauchs, 2017

1.2. How Blockchains Work

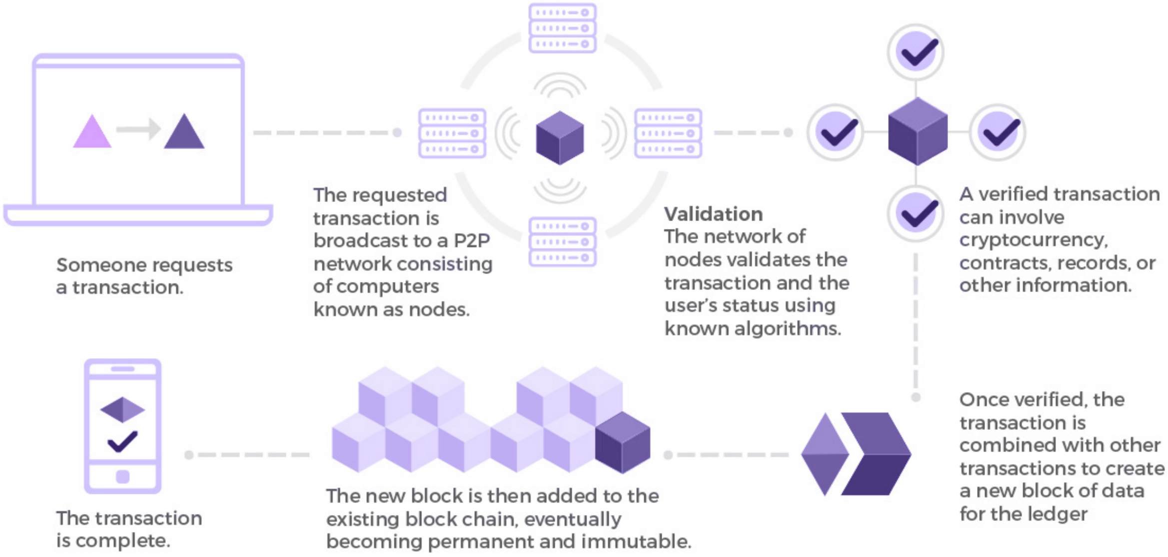
Core architectural components of blockchain include a 'block – ' containing data, the hash of itself, and that of the block before it; 'node' – a user or a computer within the blockchain ecosystem; 'chain' – a sequence of blocks in a specific order; 'transaction' – verified and digitally signed records; 'consensus' – set of rules established to carry out every blockchain operation; and 'miners' – specific nodes which perform the block verification process.

The process begins after authentication, when a node requests a transaction by broadcasting it to other nodes. The users put information regarding their transaction into a cryptographic hashing algorithm – a complex mathematical formula – and receive a set of letters and numbers that are distinct to that transaction for security purposes. Secondly, other nodes in the network check if the data has been tampered with, and reject or accept accordingly, without seeing the details of the transaction[19]. Once verified upon consensus, the transaction is complete, and a new block is created and added to the existing blockchain.

Consensus occurs in the beginning when the miners "agree on which transaction should be included in new blocks of transaction" and in the end "when the new block of transactions is actually added to the chain."[20] In that way, the desired goal of maintaining the exact same copy of the history on all nodes is achieved.[21] Since blocks are replicated across multiple ledgers, it is impossible to delete or modify information previously stored on the chain. The graphic below, visualizes how blockchain works in four steps.

15 http://www.oecd.org/finance/OECD-Blockchain-Primer.pdf
16 Permissioned: requiring authorization to perform a particular activity or activities
17 Permissionless: not requiring authorization to perform any particular activity
18 https://www.ey.com/Publication/vwLUAssets/ey-global-blockchain-benchmarking-study-2017/$FILE/ey-global-blockchain-benchmarking-study-2017.pdf
19 http://www.oecd.org/finance/OECD-Blockchain-Primer.pdf
20 https://www.frontiersin.org/articles/10.3389/fbloc.2019.00027/full#note6
21 https://medium.com/cryptronics/proof-of-work-is-not-a-consensus-protocol-understanding-the-basics-of-blockchain-consensus-30aac7e845c8

Figure 1: The Process of Blockchain



Source: (UNDP, 2018)

Through the above process, blockchain being a distributed ledger technology can ensure the following properties[22]:

1. Shared record keeping - enables a set of authoritative records to be shared across multiple parties.
2. Multi-party consensus – enables all parties to agree on the set of shared records without a central authority.
3. Independent validation – enables each party to independently verify the transaction records on the ledger.
4. Tamper evidence – enables each party to detect any unilateral or non-consensual changes to transactions.
5. Tamper resistance – prohibits a single party to easily or unilaterally change the transaction history of the ledger.

22 https://www.jbs.cam.ac.uk/wp-content/uploads/2020/08/2018-10-26-conceptualising-dlt-systems.pdf

CHAPTER
02

Usage of Blockchain in the United Nations System

The United Nations (UN) system is keen on leveraging new technologies to optimize its daily operations and accelerate its work and efforts to achieve the Sustainable Development Goals (SDGs). The benefits of increased computational power and advancements in technologies such as blockchain, the Internet of Things (IoT), Artificial Intelligence (AI), amongst others – whose roots were traditionally deep in the private sector – are now being utilized more frequently in the humanitarian, development and public sectors for the advancement of human welfare. To this end, the UN has provided a framework to leverage new technologies as outlined in the Secretary General's Strategy on New Technologies. The document aspires to use new technologies to achieve the 2030 Sustainable Development Agenda and respective SDGs in alignment with values espoused in the UN Charter, the Universal Declaration of Human Rights and the norms and standards of International Law.

The use of blockchain for social impact has seen a significant increase in recent times, with a study by a Stanford University team listing 193 organizations, initiatives and projects using blockchain for social impact[23]. Common use cases of blockchain for development and social impact are crosscutting through a range of thematic areas such as housing (land titling and tenure of security), finance (remittances, micro-insurance, reducing fraud, financial inclusion, etc.), governance and development (improving transparency in donations, transforming governance systems, etc.), and security (tracking support to beneficiaries).[24] These use cases are of interest to the UN system and encompass innovative approaches and solutions that can be leveraged in the acceleration of the achievement of the SDGs. It is important to note, however, that while these use cases are interesting, majority are pilots and no known large scale successful implementation of blockchain for social impact exists.[25]

A study of blockchain and other distributed ledger technologies in the humanitarian sector has concluded that although transparency and trust are the most cited significant benefits of the technology, other benefits such as "improved efficiency, bureaucracy and project cost savings" are important for humanitarian actors. They also note the concerns with "invisible biases" stemming from the use of automated systems.

Several UN organizations have embarked on publishing reports and papers, and hosting events and workshops to better understand the prospects of blockchain for their work. The UN Innovation Network (UNIN), for example, has established the Atrium[26] – an integrative platform for UN agencies to learn about blockchain technology and how it can be seamlessly applied in their roles and for their organizations' needs. The network has also created an online platform documenting UN system-wide implementation of new technologies by innovation, thematic area and country/ region[27].

23 https://www.odi.org/sites/odi.org.uk/files/resource-documents/12605.pdf
24 https://www.odi.org/sites/odi.org.uk/files/resource-documents/12605.pdf
25 https://www.unjiu.org/sites/www.unjiu.org/files/jiu_rep_2020_7_english.pdf
26 https://atrium.network/
27 UNIN. Projects. https://www.uninnovation.network/projects

The United for Smart Sustainable Cities Initiative coordinated by the ITU, UN-Habitat and the UNECE recently published a paper on "Blockchain for Sustainable Cities", as part of efforts to support long-term strategies on smart and sustainable cities[28]. In 2019, the UNECE published a report highlighting potential uses and recommendations for action regarding blockchain technologies in trade facilitation[29]. Other efforts include a thorough review by the Joint Inspection Unit (JIU) of blockchain technologies as applied within the UN System, in order to make concrete recommendations on the uptake of blockchain within UN operations and programs. JIU reports increasing interest in the use of blockchain applications within the United Nations System, the implementation of multiple pilots, and the examination of legal aspects of blockchain applications. However, they concluded that "the experience accumulated so far is still inconclusive as to a possible massive use [of blockchain] beyond financial services". [30]

Forbes has also recognized the United Nations for its use of blockchain technology in its second Blockchain 50 List – a list of enterprises embracing blockchain to speed up business processes, increase transparency and potentially save billions of dollars[31]. The United Nations' goLandRegistry – a proposed joint initiative by UN-Habitat and UN-Office of Information and Communication Technology (OICT) in Afghanistan – was recently featured in Forbes[32] signifying the visibility of interest by organisations within the UN System in leveraging blockchain technology. These developments, however, do not signify the UN's promotion of the technology, as full compatibility in areas of interest has not been established and due assessments, cost-benefit, and sustainability analysis have to be undertaken for all potential use cases.

So far, UN agencies are involved in three distinct activities related to blockchain;

1. producing publications and making investments,
2. organizing events and workshops, and
3. running proof of concept [33].

Blockchain use cases within the UN are emerging and are being piloted in humanitarian operations and development programs. Blockchain is used for registering and tracking purposes (as in the case of land registries or supply chain tracking), increasing transparency of financial transactions (as in the case of cash transfers to refugees), and increasing organizational efficiency (as in the case of smart contracts). However, it is important to note that most blockchain initiatives are in their initial stages and are currently either being prototyped or tested as part of a pilot process.

28 UN4SSC (2020)
29 UNECE, 2019
30 https://www.odi.org/sites/odi.org.uk/files/resource-documents/12605.pdf
31 https://www.forbes.com/sites/michaeldelcastillo/2020/02/19/blockchain-50/?sh=5e18c33b7553
32 https://www.forbes.com/sites/lukefitzpatrick/2020/12/02/the-united-nations-golandregistry-blockchain-initiative-takes-on-a-challenging-first-assignment-in-afghanistan/?sh=5dd71bba6bee
33 https://unite.un.org/sites/unite.un.org/files/session_3_b_blockchain_un_initiatives_final.pdf

The table below highlights a few examples, not exhaustive, of ways in which blockchain technology is used in the UN System. The initiatives are either at the prototype stage or have been fully piloted and scaled.

Table 2: Sample Blockchain Use Cases Within the UN

Use Case	Entity	Description
Building Blocks – Cash based transfers	WFP	A platform to deliver cash-assistance directly to beneficiaries in a transparent, efficient and secure way
e-Trade for All	UNCTAD	An application to help people from all over the world start their own online businesses
Blockchain-Based Financial Platform – Digital Wallet	UN Women	An electronic device or online service that holds assets on behalf of a user and facilitates the payments for goods and services in a more transparent and secure manner
UNICEF Innovation Venture Fund	UNICEF	Innovation Venture Fund invested in blockchain startup projects & developed application prototypes of their own
Digicus (Smart Contract Prototype)	UNICEF	Platform created for end-to-end digitized HACT processes, leveraging blockchain technology to simulate business rules and the release of funds
Cedar Coin	UNDP	CedarCoin is a digital asset created to recognize the planting event of a cedar tree in Lebanon. For each new tree planted, CedarCoins will be distributed to investors but also to local communities hosting the trees, encouraging reforestation efforts and rewarding environment-conscious behavior.
Blockchain-Based Certificates	UNICEF	UNICEF Ventures is leveraging a public blockchain, Ethereum, to make claims in a transparent and immutable way. In the first phase of the prototype, UNICEF Ventures issued certificates confirming the participation of organizations who tested in their drone corridors. Certificates have also been issued for participation in UNICEF blockchain learning courses.
GoLandRegistry	UN-Habitat and UN-OICT	UN-Habitat and UN-OICT are leveraging blockchain technology in the development of open-source digital land registry for Afghanistan. The blockchain technology in the solution, which has been handed-over and is under testing by the Afghanistan Government, is used in the last step of the property registration process where the final product – the occupancy certificate – is stored in a blockchain ledger (LTO network) providing an immutable record.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CHAPTER 03 The Potential of Blockchain Technology for Urban Development- Municipal and National Use Cases

Since its inception in 2008, blockchain technology has experienced an evolution in its usage. Not only has the technology grown in popularity, but it has also widened its scope for applicability beyond just cryptocurrency transactions, to include other function areas as discussed (section 2).[34]

The literature suggests that the application of blockchain technology is slowly expanding. Blockchain has had deep roots in the private financial sector, with applications in the development and humanitarian sector just beginning to be considered. The micro-implementation of blockchain technologies in city affairs is also gradually beginning to be observed as will be discussed further in detail. It is expected that blockchain could have some potential beneficial implications for promoting sustainable urban development. In this section, blockchain use cases implemented by municipalities and national governments are examined, using a set of defined criteria, to show the use of the technology for urban development challenges. The criteria are derived from the definition and characteristics of blockchain technology; decentralized, secure, immutable, and transparent.

3.1. Blockchain For Land & Property Management, Documenting Property Rights, and Tenure Security

Much of the world's land and property is undocumented and, in some countries, the data is vulnerable to alteration.[35] Out of the 2.5 billion people who rely on indigenous and community lands, only one fifth own the land legally.[36] Access to secure land is considered a form of economic empowerment, a safeguard against displacement or exploitation, and even a foundation of cultural identity[37] and more importantly a means to ending poverty, as evident in its inclusion in target 1.4[38] of SDG1 (end poverty in all its forms everywhere). Even where legal titles or land rights exist, basic mapping, geographic, or ownership information is often inaccurate or non-existent causing disputes[39]. Land ownership disputes fuel conflicts frequently and represent a threat to peace and security. In addition, the transfer of property, in places like Sub-Sahara Africa, is often time-consuming. For example, it takes an average of 73 days to transfer property in Kenya and 68 days in Tanzania, as compared to 30 days in OECD countries[40]. Further, the application of formal recognition for land ownership is tedious and costly[41]. These hurdles hinder the efficient operation of urban land markets and deny municipalities much needed revenue from land and property taxes.

Blockchain has the potential to improve inaccurate recording of land, tenure security and property rights. For example, if stored on a blockchain, land and property records could still be accessed in the event of a national disaster or post-conflict reconstruction. A good case in point is the 2010 Haiti earthquake. Many municipal buildings storing land title records were destroyed and it has been difficult to verify land ownership in some cases. The use of blockchain-based property systems has the potential to alleviate such problems. A decentralized, standardized system for land registration records could reduce the number of intermediaries required, increase trust in identity of transacting parties, increase process efficiencies and decrease time and cost of processing registrations and transactions. It could also improve the robustness of technology solutions relying on physically distributed data networks.

34 http://www.sciencedirect.com/science/article/pii/S0959652619333992
35 https://www.undp.org/content/dam/undp/library/innovation/The-Future-is-Decentralised.pdf
36 https://www.oxfam.de/system/files/20160302-common-ground-land-rights.pdf
37 https://www.gsb.stanford.edu/sites/gsb/files/publication-pdf/study-blockchain-impact-moving-beyond-hype_0.pdf
38 "By 2030, ensure that all men and women, in particular the poor and the vulnerable, have equal rights to economic resources, as well as access to basic services, ownership and control over land and other forms of property, inheritance, natural resources, appropriate new technology and financial services, including microfinance"
39 World Bank (2017)
40 Ibid
41 Killmeyer, White, & Chew (2017)

A number of recent cases provide insights into the ways in which blockchain is being used in different parts of the world:

a. **GEORGIA: EXONUM LAND TITLE REGISTRY** - Partnering with Bitfury (a company that provides blockchain solutions), the National Authority for Property Registration (NAPR) of the Republic of Georgia (with the advisership of renowned economist Hernando de Soto) developed a blockchain-based platform that provides its citizens with a digital certificate of their land title[42]. The land registry uses both permissioned (the Bitcoin platform) and non-permissioned (using the Exonum platform) blockchains. The registration is done in four easy steps; i) a citizen submits a registration request just as in the tradition platform, ii) the notary registers the land title on the private blockchain, Exonum, iii) hashes of the Exonum private blockchain are anchored onto the public Bitcoin blockchain ensuring transaction integrity, and iv) the NAPR provides a cryptographically proven digital certificate which is also published on the public Bitcoin blockchain[43]. In 2018, Georgia registered over 1.5 million land titles on their blockchain-based system[44]. Registration is now done in minutes unlike previously when it took about 3 days. Further, since the technology became operational, land titling costs have been reduced by 90%[45].

b. **GHANA** - On the African continent, Ghana is implementing perhaps the most renown land registry blockchain-based system. Ghana has had a long history of corruption and land- based conflicts, with an estimated 78% of land being unregistered[46]. Further it took about two years to complete the process of land registration by the Ghana Land Commission, and local governments are unable to verify property taxes due to paper-based systems[47]. Bitland, a Ghanaian start-up partnered with Ghana Land Commission in building a blockchain-based land registry. Bitland is using OpenLedger, which is built on top of the BitShares platform and its MIT-licensed Graphene blockchain technology, as the basis of their blockchain. By 2017, Bitland had registered more than 5,000 properties in the city of Accra and had more than 500,000 other properties in the pipeline[48]. Citizens obtain a unique ID that is linked to their property as well as a digital certificate validating their possession in case of a dispute.

c. **AFGHANISTAN** - As part of its "City for All" program UN-Habitat, in collaboration with the United Nations Office of Communication and Information Technologies (UN-OICT) is leveraging blockchain technology for secure and transparent land records management in Afghanistan as part of a larger rebuilding process. Blockchain is specifically used at the end of the land registration process when occupancy certificates are registered and signed. The documents are hashed (passing data for encryption) and stored in the LTO Network public blockchain. The LTO Network blockchain uses the Proof of Importance consensus algorithm that is a variation on Proof of Stake (PoS) algorithm[49]. The immutable version of land records is being created in goLandRegistry, and its blockchain-anchored version can serve as the basis for other government services, such as urban planning, citizen engagement, tax collection and revenue generation.

42 Kundu (2019).
43 Nascimento (ed) et al. (2019).
44 OECD (2019)
45 Ibid
46 Kshetri & Voas (2018)
47 Dubrule (2017)
48 Ibid
49 LTO.network Blockchain for Decentralized Workflows - https://ltonetwork.com/documents/LTO%20Network%20-%20Technical%20Paper.pdf

Box 1: **Property and Real Estate Transactions via Blockchain in Dubai**

In 2017, through the Dubai Department of Land (DLD), the city of Dubai became the world's first government entity to conduct all property transactions through a blockchain network. The DLD created and uses a blockchain system that records all real estate contracts including lease registrations. The system cleverly links with local utility databases, including the Dubai Electricity and Water Authority (DEWA), the telecommunications system, and other property related bills.

The platform's ability to connect with personal tenant databases including the Emirates Identity Cards and the validity of residency visas, allows for 100% digital transaction, without paperwork, brokers, and the need for physical presence. In addition, the platform helps in linking buyers, sellers, renters, and tenants, and provides unique portfolios for users allowing them to track and manage their properties.

The above case studies make it clear that blockchain may have some applications in conventional land and property registries. From the examples given above, the major value addition blockchain-based conventional land registries have is the immutable and transparent recording of individual property and ownership data. The security offered by blockchain may be useful for the safe and digital storage of documented property rights, which may have important implications in the provision of security of tenure, a challenge that has long persisted in developing countries.

However, while blockchain may offer significant record-keeping benefits, there is no evidence yet of its capacity to solve other complex land-related issues. This includes mapping surveys, initial registration, digitization of records, and aspects around community land rights, and inclusion, especially with tenure security denied to groups such as women. Implementation of blockchain technology may also not do much in the presence of inhibitive land administration policies. For example, costly inheritance and rights transfer processes may undo the benefits of registration in the event of a death or divorce. Further, blockchain, like any other technology, only works as a system to register and keep legitimate records and cannot resolve the "GIGO" (garbage-in, garbage-out) computer science concept applied to data input and output. Blockchain, as any other non-blockchain based system, will diligently store and share incorrect data until it is corrected. No technology solution alone will solve the challenge of the initial mapping and identification of rights holders considering the significant gaps in governance, infrastructure, and capacity at the local level. It might also not be able to manage claims by traditionally excluded groups such as women or youth who are currently excluded from mainstream systems and would therefore struggle to be part of any technology solution system (including blockchain). This is the principal challenge of land management in developing countries. Blockchain, though, better than any other applied tech, can provide unique support to formal and informal processes that governments and society at large can put in place to build trust and resolve conflicts around data veracity. Through its inherent use of open cryptographic algorithms which autonomously store data, lock its authenticity, and do not require central authorities to validate and certify, blockchain technology can leverage consensus building on data accuracy and land ownership titles.

3.2. Blockchain for Urban Basic Services

d. With the global urban population rising rapidly, especially in developing regions, economic, social and environmental systems will come under increased pressure to sustain new populations. Significant investments in new urban infrastructures will need to be made in order to complement civil amenities and services such as electricity, water, housing, and recreational facilities which are already under pressure[50]. These changes call for streamlined, efficient and affordable urban basic services to improve the quality of life for urban dwellers. Blockchain may have the potential to improve urban basic services and increase equitable access to services. This includes its application in urban freight for tracking the movement of goods and services across borders and application of the technology in e-mobility functions such as sharing of e-bikes and e-scooters.

3.2.1. Waste Management

e. Waste management is a critical service in urban environments. The improper disposal of waste contributes to pollution and unsanitary conditions that can increase the likelihood of disease transmission and public outbreaks. Several key challenges have been identified with regards to waste management in a study by Ongena et. al, 2018: fraud and manipulation, wrong or loss of information, manual processes, lack of knowledge about technology and lack of control[51]. While recognizing that blockchain is not a panacea for the above challenges, the authors recommend leveraging blockchain's immutability characteristic to overcome the challenge of storage of data and information.

50 https://www.ircwash.org/sites/default/files/822-IN93-13407.pdf
51 Ongena, Guido; Smit, Koen; Boksebeld, Jarno; Adams, Gerben; Roelofs, Yorin; and Ravesteyn, Pascal, "Blockchain-based Smart Contracts in Waste Management: A Silver Bullet?" (2018).BLED 2018 Proceedings. 19. https://aisel.aisnet.org/bled2018/19

Drawing from this study, blockchain could be used to aid waste management in two ways. First, it can assist in the digital tracking of waste information as it goes through the process and facilitate the in-depth analysis of the supply chain. Second, it can be used in solutions for incentivizing people to adopt more environmentally friendly measures. This has been the case in some parts of Northern Europe where blockchain has been used to incentivize people to trade recyclables such as plastic containers, cans, bottles, etc., using cryptographic tokens[52]. This case in South Korea shows that it is being used in recycling efforts.

JEJU PROVINCE, SOUTH KOREA[53]: The province of Jeju in South Korea has implemented a blockchain-based system to efficiently manage electric vehicle waste-batteries. Funded by a government grant and the private sector, the province launched the management system for distribution history for vehicle batteries in 2016. The system tracks the history of the receipt of waste-batteries collected at the Jeju Technopark Electric Vehicle Battery Industrialization Center. The data collected includes information about various inspections, classifications, and releases, and is recorded via blockchain.

3.3. Blockchain for Urban Governance and Social Inclusion

With 2.5 billion more people expected to inhabit the world's urban areas by 2050, urban areas and cities will come under increasing pressure to provide corresponding services. As demographics change in many countries, governments are facing greater demands from citizens over the range and quality of services[54]. In addition, there is a need for governments to improve their citizens' trust by enhancing responsiveness in service delivery and transparency. Poorly planned urbanization can result in congestion, pollution, higher crime rates, and increasing inequality and social exclusion. Data also suggests that inequality is greater in urban areas than in rural areas, especially in Africa and Latin America, with larger cities being more unequal than smaller cities[55]. Such imbalances often cause social pressures and may result in violence and political upheavals. The role of improved urban governance will be key in alleviating such challenges, improving participatory mechanisms, and strengthening accountability and transparency systems within public institutions.

Digital transformation in governance systems is often seen as critical in developing better governance structures. The unique characteristics of blockchain technologies imply potential benefits in governance. Blockchain offers the opportunity for trust, consensus, and data driven governance in urban management. The immutability of blockchain technologies implies that citizens can be uniquely registered and identified in unmodifiable ways and with increased data protection. Further, immutability in municipal governance will encourage transparency and accountability in government procedures, with significant effects on the reduction of corruption in public entities[56]. Blockchain will allow for the provision of the most repetitive local government services through smart contracts, eventually increasing government responsiveness, reducing service delivery times, and increasing trust[57].

Below are a series of case studies which show how blockchain is being used to strengthen governance systems and make them more inclusive.

a. **DUBAI** - Dubai has initiated ambitious smart city goals including becoming the first city to be fully powered by blockchain by 2021[58]. The Dubai government is moving all its transactions onto blockchain technology, thereby eliminating some 100 million paper transactions. It is estimated that this move will save the Dubai government $1.5 billion annually, which is equivalent to the cost of building one Burj Khalifa (the world's tallest building)[59]. Further, blockchain is expected to strengthen the city's governance, helping to ensure a reduction in the time required to process documents by up to 25.1 million hours, and reducing CO_2 emissions by 114 Mtons from trip reductions[60].

b. **HAARLEM, NETHERLANDS** - The municipality of Haarlem has developed a proof of concept that utilizes blockchain to verify legal documents. Under the Haarlem Securities Project, the system allows for digital attestations of registrations. For example, residents can prove residency to a housing organization without visiting the town hall. The technology is also used to register citizens in the personal records database, and issuance of certificates is digitized[61]. The software is released as open-source and can be accessed by governments, municipalities, and residents.

52 https://www.tandfonline.com/doi/pdf/10.1080/00207543.2018.1533261
53 https://thenews.asia/jeju-island-use-blockchain-to-limit-wasted-vehicle-batteries/
54 OECD (2016)
55 United Nations, 2020a
56 Govela, A. - https://www.metropolis.org/sites/default/files/metobsip5_en_1.pdf
57 Ibid
58 Xische & Co. https://www.smartdubai.ae/docs/default-source/publications/state_of_play_blockchain.pdf?sfvrsn=3c95f894_0
59 Ibid
60 IDC (2020)
61 ICTU (2017)

c. **NEW YORK** - A private sector initiative, "blockchain for change" in New York, is using a blockchain-powered platform to extend services to its vulnerable and often underbanked population. The application is consolidating government and social benefits accruing to its low-income population. As the current American social security system requires physical documentation, many vulnerable people such as the homeless do not have access to such crucial services. With implementation of the blockchain technology, low-income and homeless groups (who lack identification) receive a virtual wallet with a unique ID that establishes an immutable profile for the residents. In addition, the platform enables those with poor or no credit to build a chronological history of transactions without the high fees, and they can eventually leverage the history to obtain micro-loans from financial institutions.[62]

Identity management in cities has become increasingly important. By 2050, 67% of the world population will live in cities and urban areas, making human data even more important. With rapid urbanization, data on housing, vulnerable populations, immigrants, etc., will be crucial for service-delivery. The above use cases illustrate that blockchain is potentially useful in city and urban population data management, as at the core of the use cases reviewed is the management and storage of records. As the world places more emphasis on the imperative to develop robust social protection and benefits mechanisms post-COVID-19, blockchain technologies could serve as the basis for storing benefits data, providing unique IDs for urban residents, and transferring said benefits.

However, it must be noted that technology could exacerbate inequalities and promote discriminatory habits. Given the encroaching power of states and global corporations in collecting and analyzing personal data, the time to protect digital and physical rights is ripe. Guberek & Silva (2014) discuss the challenges that technology can pose in the advancement of social and human rights, including increasing threats to human rights activists and vulnerable populations in repressive contexts. Similarly, concerns have recently been raised by the UN Special Rapporteur on racism, xenophobia, and related intolerance, demonstrating how governmental and humanitarian data collection has been linked to human rights violations[63]. While improving technology is important, it is also imperative to consider the wider human rights context in the innovation process. Technology applications should cryptographically embed human rights and data privacy standards in their code and should only be taken as a means, while enhancing human rights is seen as an end goal.

3.4. Blockchain for Urban Energy Systems

Cities dominate the world's energy consumption, and by extension, greenhouse gas emissions. While cities only occupy 3% of the world's total land mass, they consume two-thirds of global energy and account for about 70% of global CO2 emissions[64]. Energy consumption in transportation, electricity & heat, buildings, and manufacturing & construction is the world's largest contributor to global GHG emissions, accounting for a whopping 73%[65]. It is estimated that 70 percent of the world's cities are already experiencing the effects of climate change, giving them the greatest incentive (and opportunity as innovation hubs) to transition to energy-efficient systems[66]. Cities around the world are culprits of rampant energy wastage. For example, analysis by Green Alliance shows that energy wasted by the city of London's offices could power 100,000 homes and is costing business £60 million in unnecessary energy bills[67].

Blockchain technology has a wide range of potential uses and benefits for the energy sector. Implementation of blockchain in urban energy systems could increase energy efficiency, reduce wastage, and open new economic benefits and markets, as the Brooklyn Microgrid Project demonstrates (see below). It could also form the basis of a framework to accelerate the transition to renewable energy usage by business and the construction industry. For instance, by using green electricity certificates, energy producers could be incentivized to generate electricity from renewable sources. Blockchain could facilitate the issuance of these certificates, which could be traded and priced accordingly, providing an incentive for further investments in green energy[68].

Another easily implemented use of a blockchain-based energy system is 'electricity wholesale trading'[69]. Current electricity marketplaces already depend on data reliability. With blockchain, these marketplaces could be transformed into tamper-proof, cryptographically enhanced systems that match electricity demand and supply, as well as the corresponding purchases. For example, smart contracts could ensure that electricity is only requested when local green energy is available[70]. This has significant implications in opening potential new markets and increasing energy efficiency. For detailed applications, see: Andoni, et al. 2019[71].

62 Nation League of Cities, 2018
63 United Nations, 2020b
64 WEF (2020)
65 WRI (2020)
66 C40 Cities (2012)
67 Green Alliance (2020)
68 FSR Energy (2019)
69 Ibid
70 Ibid
71 Andoni, et al. (2019)

BROOKYLN, USA - The Brooklyn Microgrid project in New York City is a transactive peer-to-peer (P2P) energy trading platform on Exergy blockchain. A microgrid is a localized energy system operating independently from national traditional systems. The blockchain system in Brooklyn's energy system allows residents to transfer electricity credits to a secure, low-cost, and public digital ledger that all users can access[72]. Residents can, for example, finance solar installations through the sale of excess solar energy to neighbors. While the system allows for the traditional grid to be used as a back-up, the microgrid is cost-effective, self-financing, and reduces the municipality's energy wastage and capital expenditures associated with traditional grids.

Blockchain technologies in the energy sector are considered to have the potential to accelerate the path towards renewable energy usage through incentive mechanisms and the saving of significant amounts of excess energy. Energy wastage in cities could also be reduced through the crypto trading of excess energy using tokens, for example. While blockchain in the energy sector shows some promise, the literature urges consideration of blockchain's value add and competitive advantage against other potentially cheaper and readily available centralized databases[73].

72 Nation League of Cities (2018).
73 Andoni, et al., 2019

CHAPTER 04 Risks and Concerns to Implementing Blockchain Technology for Sustainable Urbanization

The literature reviewed for this paper suggests that the blockchain ecosystem is complex and operates in often complex contexts, has been evolving, and will likely continue to evolve. As understanding of this technology continues to take shape, organizations and other stakeholders will likely continue creating their own blockchain networks for specific use-cases. Implementors of the technology will, however, have to contend with complex issues that surround blockchain's ultimate effectiveness in the broader governance and infrastructure systems in which it is being proposed. This section explores some of the perceived risks and concerns that implementors of blockchain have experienced and are perhaps likely to face.

Governance, Trust and Inclusion

A decentralized form of governance is likely to be opposed in some quarters. The success of widescale blockchain initiatives is therefore dependent on the robustness of structure and power relations within the context of implementation. This has been demonstrated in the case study from Afghanistan's goLandRegistry, with authorities taking steps to enact laws in parliament allowing for the use of blockchain technologies. On the other hand, women in Afghanistan still have to follow many traditional norms, and while some are being granted tenure security, their capacity to participate in a broader blockchain governance system (or any other technology-based system) might be limited.

Blockchain is among the technologies, such as big data and AI, causing a shift in power relationships. Technology and data being provided by private corporations are increasingly being used in the public sector, and traditional modalities of law and governance are doing little to streamline, contain, and manage power shifts[74].

As a result, moving towards a wide scale implementation of blockchain will require a significant shift away from the traditional way of doing things. While people are used to centralized systems, blockchain implementation will require placing trust in a decentralized, independent system. A lot of skepticism and doubt may be experienced and education on how blockchain-based system use cryptographically exact algorithms is still very much required at all levels of the social construct. Significant thought and analysis must be undertaken to predict behaviour and attitude towards blockchain systems.

Further, the technological construct of blockchain technology risks being inherently exclusionary. Access to electricity and the internet is important in the implementation of blockchain solutions. Intra-urban inequalities in access will need to be addressed before any widespread implementation of blockchain. Moreover, the question of universal accessibility of blockchain, either nationally or within a municipality, by all population groups should be centre stage, but often is not. For instance, the benefits of blockchain and any other technology may not be extended to women living in oppressive contexts where they are not allowed to inherit land for instance, or, in some contexts, own it. Accessibility issues also extend to groups such as migrants and persons with disabilities, who may experience affordability and usability challenges of any technology solutions. Governance systems therefore have significant influence on the success or failure of blockchain systems. Not only should governance and regulatory frameworks surrounding blockchain ensure equity, but authorities must also consider incentivizing the most vulnerable groups to improve accessibility and build trust in the same way they would do for any other technology-based solutions.

Regulatory and Jurisdictional Concerns

There is currently no harmonized regulatory policy that governs blockchain networks. Since the nodes of a blockchain network may span multiple national jurisdictions, it is often difficult to establish which jurisdiction's laws and regulations apply to a certain blockchain transaction. There is a risk that a transaction may fall under every jurisdiction in which a node in the blockchain network is situated, resulting in an

74 Zwitter & Hazenberg, 2020

overwhelming number of laws and regulations that might apply to transactions in a blockchain based system[75].

Furthermore, regulatory mechanisms across countries regarding blockchain are either extremely varied or non-existent, with some countries encouraging the adoption of the technology (e.g., France) while others are being cautious about its implementation (e.g., Spain)[76]. In addition, legal enforceability of smart contracts is limited[77]. Since smart contracts are not legally binding, there is a risk of enforcement gaps if one party voluntarily breaches the contract. Other regulatory gaps regarding blockchain include the taxation of transaction revenues, taxation of 'crypto-assets', and the regulatory gaps existing when raising capital through Initial Coin Offerings (ICOs)[78].

The UN Commission on International Trade Law (UNCITRAL) Model Law on Electronic Transferable Records recently adopted in Singapore provides functional equivalence between paper-based transferable documents and electronic transferable records and could lead the way to "governance" in blockchain-based implementations, but more work is required to review the impact of multiple jurisdictions on blockchain records[79].

Security and Privacy Concerns

So far, blockchain technologies have proven resilient against malicious attacks. However, this is not to say that blockchain systems are completely secure. In fact, there have been several attacks on the Bitcoin network, with the most targeted services being currency exchange and mining pools[80]. While public decentralized blockchain systems are designed to have consensus on many nodes, questions still abound about the possibility of an attack from a collusion of miners across different nodes in what is called a '51% attack'[81]. This would occur when 'attacker' nodes take control of majority of the computational power of the blockchain system. It has also been demonstrated that blockchain networks are susceptible to selfish miners if they achieve even a small portion of hashing power[82]. Selfish miners tend to gain more revenues than 'honest' miners by not broadcasting their blocks and only revealing them to the public if some requirements are met.

The distributed framework of blockchain may, though, reduce the challenges of securing centralized systems from insider threats and malicious insider attacks that may lead to data alteration by insiders with legitimate access to systems and their underlying infrastructures.

Privacy issues are also a concern in blockchain networks. While blockchains maintain a certain amount of privacy, all transactions through the network are transparent and can be accessed by the public (for non-permissioned blockchains). The public can see all transactions but without information linking to individual identities. However, blockchain networks may not be able to guarantee complete privacy. Experimental evidence suggests that it is possible to reveal identities through linking pseudonyms to IP addresses even when users are behind firewalls[83].

While blockchain principles are sometimes at odds with privacy legislation, technologists have concentrated in resolving difficult problems like the technical implementation of the "right to be forgotten" and data retention periods

75 Salmon & Myers (2019)
76 Dewey (2019)
77 Fulmer (2019)
78 Salmon & Myers (2019)
79 https://www.businesstimes.com.sg/opinion/adoption-of-uncitral-model-law-heralds-a-quiet-revolution-in-digital-trade
80 Yli-Huumo, et al. (2016)
81 Ibid
82 Eyal & Sirer (2014)
83 Biryukov, Khovratovich, D., and Pustogarov (2014)

prominently featuring in the EU General Data Protection Regulation (GDPR). As an example, the LTO Network has engineered mechanisms to ensure that data privacy is handled in miniature private blockchains with transactions anchored in the LTO permissionless public blockchain[84].

Usability and Scalability

Compared to well-configured centralized databases, blockchains will generally underperform. Blockchain technologies will have to prove that they can provide the scalability and speed required for a wide scale range of applications. Blockchains currently have a lower transaction processing throughput and higher latencies[85]. For example, the throughput in the bitcoin network is currently maximized at 7 TPS (transactions per second). Other centralized processors have much higher throughput, such as VISA (2,000 TPS) and twitter (5,000 TPS), although newer generation of blockchain framework like Ripple operate at up to 1,700 TPS, EOS at 4,000 TPS and NEO at 10,000 TPS with the aim being to support 100,000 TPS in future releases[86].

Blockchains also have greater latency periods as compared to other processing networks. To achieve the security promised by blockchains, more time needs to be spent on one block per transaction. On the bitcoin network, for instance, it takes roughly 10 minutes to complete one transaction, as compared to, say, VISA which takes only a few seconds[87]. Latest developments brought latency to very low levels and Aleph Zero claims to have reached 40,000 TPS resulting in confirmation of transactions in as little as 0.6 second[88].

Economic Viability and Costs

While blockchains offer significant cost savings by circumventing intermediaries, they have high development costs[89]. Blockchain systems require costly new infrastructure such as custom ICT equipment and software. Other possible high costs associated with blockchain are verification and validation of transactions, which differ depending on the type of blockchain. For example, on the bitcoin network which uses a PoW (Proof of Work) consensus algorithm, total transaction validation costs are estimated to be as high as $600 million annually, which does not include the high initial costs[90]. This was one of the main concerns with instituting a blockchain-based land registry in Honduras by stakeholders[91]. Furthermore, the application of blockchain in some use cases may not be entirely necessary or economically viable. For example, energy transactions can be recorded in conventional databases designed to recognise linkages between stored information. These technologies are readily available and are faster and less costly to operate[92]. This reduces the competitive advantages of blockchains for some uses although with the switch to Proof of Stakes type of consensus (including for the second largest blockchain, Ethereum) energy levels required to run the network would be commensurate with using centralized systems[93].

Energy Consumption

Implementation of blockchain technology represents a major challenge in sustainable usage of resources. While determining the exact energy consumption of blockchain technology is difficult (due to the uncertainty of the number of participants, hardware properties, and the effort they put into mining), researchers can obtain good general estimates[94].

For example, it has been estimated that Bitcoin, which uses PoW systems for consensus, has an annual electricity consumption of between 60 and 125TWh[95]. This is comparable to the annual electricity consumption of entire countries such as Austria (75GWh) and Norway (125GWh)[96]. This amount of energy requirement poses great concern in a world which is already climate change-insecure, and has immense implications were blockchain technologies to be adopted on a wider scale. In fact, it has been estimated that if blockchain technologies were to be adopted at roughly the same scale as technologies such as VISA, the adoption alone could produce enough CO_2 emissions to push warming above 2°C within less than three decades[97]. High energy consumption of blockchain, therefore, suggests an implicit risk of increased power bills and expenditure passed on to residents, which may increase budgetary pressure on poorer residents.

Energy consumption in blockchain systems is dependent on the algorithmic system of validating transactions, a process called "reaching consensus". This process is facilitated by different algorithmic systems such as Proof of Work (PoW), Proof of Stake (PoS), Practical Byzantine Fault Tolerance (PBFT), Ripple, and Tendermint[98]. Major blockchain platforms such as Bitcoin and Etherium use PoW algorithmic systems that have been faulted as energy intensive, which is why Ethereum is implementing a switch over from the PoW to the PoS algorithmic systems.

84 LTO Netowork - https://blog.ltonetwork.com/lto-network-blockchain-gdpr-made-possible/
85 Christidis & Devetsikiotis (2016)
86 https://www.blockchain-council.org/blockchain/five-best-blockchains-with-high-transaction-speeds-in-2019/
87 Yli-Huumo, et al. (2016)
88 https://alephzero.org/blog/what-is-the-fastest-blockchain-and-why-analysis-of-43-blockchains/
89 Andoni, et al. (2019)
90 Mougayar (2015).
91 Graglia & Mellon (2018)
92 PWC (2017)
93 https://ethereum.org/en/developers/docs/consensus-mechanisms/pos/#top
94 Sedlmeir, Buhl, Fridgen, & Keller (2020).
95 Ibid
96 Ibid
97 Mora, et al. (2018).
98 Zheng, et al. (2017)

24

CHAPTER 01

Conclusions

The future of blockchain is anything but certain. While some argue that the trusted establishments and institutions at the center of transaction systems will soon cease to exist, other conservative voices posit that blockchain will have a relatively low impact on ways of life and business models. The truth is likely somewhere in the middle. As understanding of the blockchain technology deepens, policymakers and organizations will have a better discernment of where blockchain best fits in our society. Interest in blockchain will likely increase in the future, albeit cautiously. In pursuit of providing solutions to concrete problems, start-ups, different levels of government, and multinational organizations will likely identify the technical, organizational, cultural, and talent changes necessary to realize new benefits – and then scale what works.

Blockchain technology is not magic, or a panacea for the challenges of urban development, but it does have some interesting capabilities. Blockchain presents opportunities for advancing the Sustainable Development Goals agenda, at least to some degree. The use of green certificates may incentivize a transition towards a green future, for example. It can potentially improve trust in governance systems through the establishment of transparent and tamper-proof public ledgers. Further, blockchain may have some implications on creating new business models and markets, such as the trading of crypto-tokens and excess energy credits. Its applications span across sectors such as healthcare (accurate health records), education, land, etc.

However, it is important to be cautious of the risk of over-romanticizing the use of blockchain or any other technology. While it may have intriguing potential applications, blockchain, as with other technologies, cannot replace the fundamentals of development, that is, human-centered approaches. Blockchain should only be used to complement already established governance, planning, and economic systems.

Blockchain (as are other technologies) is essentially an infrastructure for trust, but not inherently or necessarily for truth. This implies that while it may be used to store information accurately and immutably, the accuracy of the information or data has to be truthful and transparent from the initial step, and therefore be underpinned by strong and inclusive governance frameworks. Blockchain and any other centralized technology solutions implemented are heavily dependent on institutional mechanisms and regulations, as well as goodwill from the authorities who influence their continued use. In all contexts, this remains a genuine challenge.

Recommendations for Consideration by Urban Authorities and Managers

Blockchain is still a relatively nascent technology offering interesting capabilities for impact. Its implementation should, however, be carefully punctuated by caution as blockchain presents certain risk factors as discussed in Section Four. By averting these risks and concerns, blockchain implementation could be beneficial for cities. Discussions in previous sections have generated recommendations for consideration by city managers looking to set up blockchain systems. The recommendations are anchored on the following four key pillars: Governance, People, Economics, and Data.

a. Ensure Coherence Alignment of City and Urban Priorities with Blockchain Projects

Urban authorities should avoid the temptation to over-romanticize blockchain and prioritize impact over the technology itself. A key question that urban authorities must consider, is whether blockchain technology is necessary. Blockchain, as with any other technology, should only be used when there is an absolute need and when there is a clear vision of how it could improve efficiency, reduce costs, or even increase revenues. The added value and return on investment as a result of using blockchain must be considered.

Further, comprehensive feasibility studies and pilot testing to ascertain the applicability of blockchain technology in a particular context is critical with the financing and technical resources required for this exercise being taken into consideration. It is vital for policymakers to appreciate that a potential blockchain application does not equal necessity. For example, in a city with relatively well-established and functioning land registries, blockchain may offer little added value. Such cities may however benefit more from blockchain through the creation of new business models and markets, such as those in the trading of crypto tokens.

b. Update All Relevant Urban Records and Databases

Blockchain is essentially a data storage and transactional technology. Beyond that, its applications are very limited. While its storage capabilities are impressive, it does not verify the truthfulness or accuracy of the data and information that is fed into it like other systems. City authorities must therefore update, clean, and verify all records and data before it is fed into the blockchain system in the same way they currently do for centralized systems. For instance, crucial records on citizen identities, land registries, city waste management, supply chain data, etc., must be accurate before implementation of blockchain technology. The risks of inaccurate data in blockchain's immutable platform are immense. Not only would the city or country operate on false information, but it would potentially result in conflicts and legal disputes, especially in sensitive areas such as land ownership information and identity management. While incorrect data entries can be corrected by a new transaction, it is imperative that city managers ensure initial data accuracy. Cities should therefore invest in comprehensive mapping exercises, data retrieval and recovery, as well as backup systems.

In addition, cities should invest in digital databases or upgrade to systems that are blockchain-compatible. Cities considering this technology must take advantage of the fourth industrial revolution (4IR) by increasing investments in robust civic technology. Blockchain provides an opportunity for cities to leapfrog technological developments towards sustainable smart city goals.

c. Integrate and Update Regulatory Requirements for the Implementation of Blockchain Technologies

In many cases, any use of new technologies by government authorities at all levels may have to be included within regulatory frameworks. Many new frontier technologies will have significant implications, especially with regards to sensitive personal data. Urban authorities looking to implement blockchain technology must ensure that its use is supported by law, and there may be need to enact new or special regulatory provisions. For example, basic regulations on activity and online publishing of personal data such as land records, may require specific legal provisions.

Government and city technologist must be engaged in evaluating the adoption of different blockchain frameworks to ensure a match with existing and/or forthcoming regulatory requirements as well as use cases.

Further, authorities should consider regulatory requirements pertaining to trading in crypto tokens as may be the case in many blockchain potential uses. Blockchain has the potential to create new business models and markets which support more complex transactions. In this regard, increased use of blockchain will likely see increased use of 'alternative currency' in transactions. New forms of trading must be included in national and local government regulatory frameworks.

The use of blockchain technology will also likely be tied to smart contracts. While smart contracts are essential, they are not necessarily legally enforceable. This implies that more regulatory mechanisms will have to be established to ensure that blockchain users do not voluntarily or involuntarily breach smart contracts.

d. Mitigate Exclusionary Risks of Blockchain Technology

Blockchain is still a nascent technology whose implementation may risk excluding some members of society. Broadscale blockchain implementation should be accompanied by training and capacity-building programs for community members who may face difficulty in usage. For example, in some cities, the capacity of women to participate in a blockchain initiative might be hampered by broader cultural challenges and stereotypes around women. Those living in smaller urban centers or informal settlements might not have the facilities to harness the potential of blockchain. Further, the city must emphasize building simple systems that are easily accessible and can be used by all. Blockchain platforms can be configured to function offline, especially in developing countries where internet penetration and usage is lowest. This will limit exclusionary risks for users who may not be able to afford internet bandwidth, and for other groups that may experience difficulty with online systems.

e. Capacity-building; From General Awareness to Technical Expertise

The adoption of blockchain for urban development will be easier with the availability of expertise. Capabilities should extend beyond the general knowledge of blockchain technology to include technical and managerial capacities. Capacity building should be undertaken at different levels of government; from policy making to IT operations. Further, if blockchain is to be implemented on a wider scale, such as at city or national level, awareness programs should be conducted to build residents' capacities and trust in using the technology.

f. Blockchain Requires a Set of Pre-conditions for Successful Application in Urban Development Contexts

Blockchain, as an emerging and new technology, comes with as much concern as potential. Even as the technology is still nascent, blockchain needs to evolve into a platform that delivers real social impact through its implementation around clear use cases. However, while blockchain as a technology is a necessary condition for this process, it is not sufficient. The discussions and case studies examined in previous sections suggest that there are clear conditions that must be met for blockchain to deliver the impact required for sustainable urbanization. This section will discuss the main pre-conditions for success required for blockchain implementation.

Clearly Defined Need

When implemented as a stand-alone solution (and not plugged into a section of already existing systems as in the goLandRegistry), large-scale implementation of blockchain will likely require huge initial capital outlays, changes in business models to accommodate the technology, and sufficient technical capacity. Its implementation therefore requires prior intensive planning and research. As observed in the previous section, implementing blockchain may not be economically viable for some uses, especially where faster and less costly options are available. Policymakers must avoid the temptation to impulsively adopt blockchain, and clearly identify a need or a problem that seamlessly fits with the technology. The adoption of blockchain should not, therefore, be based on the availability or 'attractiveness' of the technology itself, but rather on an issue or problem that requires its solution.

Sufficient Operational Capacity and Digital Infrastructure

Blockchain is still a relatively nascent technology and many still struggle to understand its functionality and applications. As noted above, implementing blockchain will require new hardware infrastructure (e.g., data banks that support blockchain) and specialized software. Handlers of the technology will need skills in different fields including advanced software development, ethical hacking for security purposes, and in-depth knowledge in specific sectors where the technology will be applied. In addition, widespread implementation of the technology will also require a certain minimum level of digital literacy among the population if the public is to interact with blockchain systems. Technological know-how will be required to provide solutions to the challenges associated with blockchain, such as high energy consumption, low transaction rates, and high latency periods.

Furthermore, issues around bridging the digital divide must be addressed if blockchain is to be adopted on a large-scale. As of 2018, only 47% of the world population was connected to mobile internet99. However, vast regional disparities exist. Sub-Sahara Africa, South Asia, and the Middle East had the lowest mobile internet connectivity penetration rates with 24%, 33%, and 40% respectively. This is as compared to North America, Europe and Central Asia, and East Asia and the Pacific with 75%, 60%, and 56% respectively100. In some regions, human capital differences in digital literacy will hamper the successful implementation of blockchain, and any other technology solutions requiring connectivity, and policymakers will require to take such literacy into consideration during implementation.

Regulatory and Governance Frameworks

Regulatory grey areas in blockchain are some of the biggest concerns in the consideration of the technology as a solution. Standardized frameworks should be in place to harmonize blockchain activities. While some progress with regards to data protection has been made through the enactment of the European Union General Data Protection Regulation (EU GDPR) for instance, specific action should be considered for blockchain and similar activities. As blockchain ecosystems evolve and more stakeholders get involved, standardized legislative frameworks adopted by national and municipal authorities will be imperative in ensuring the ethical and optimal usage of the technology. Accountability systems in blockchain may in future be crucial in settling disputes. Inclusion of references to real-world contracts in smart contracts may be a start101.

Further, legislative frameworks on blockchain revenue taxation are increasingly becoming relevant, as the application of existing tax frameworks to digital economies has posed challenges to national and global tax authorities. For example, legislation on taxation of cryptocurrency assets (as a capital gains tax) or issuance of utility tokens (taxed as an income) should be explored. In addition, trading itself, e.g., of credits or tokens on the blockchain network is still not covered by legislative provisions and should be explored. Moreover, smart contracts are not necessarily binding. As such, it is imperative for smart contracts to be included in traditional legal constructs.

Finally, blockchain may face significant implementation inhibitions in contexts where local, state, or national laws do not allow for blockchain use. For example, in the state of Chandigarh in India, federal laws do not allow land ownership records to be published online102. Using blockchain in such a case would be unlawful if the information can be easily retrieved by anyone. However, blockchain applications tend to only publish the cryptographic representation of the transaction, which can only be decoded with a private key, hence reducing the risk of violation.

99 GSMA (2019)
100 Ibid
101 Christidis & Devetsikiotis (2016)
102 Wharton University of Pennsylvania, 2018

Reliable Data

Data is at the center of any blockchain project. Reliable data holds the key to a successful and transparent blockchain project. Blockchain, or any other technology, alone will not solve the problems associated with urban areas and associated data issues. Increasing efficiency in urban service provision will require the feeding of available data into blockchain systems. If the data is unreliable or tampered with prior to the implementation of the blockchain project, the same urban challenges will persist, if not be exacerbated.

Checklist to Guide City Managers on Blockchain Implementation

Theme	Considerations	Yes	No
Urban Needs-Solution Analysis	Has the city identified a clear problem?	☐	☐
	Has the city conducted a feasibility study/policy analysis for blockchain implementation?	☐	☐
	Has the city conducted a pilot study?	☐	☐
	Have other alternatives been considered?	☐	☐
Operation and Infrastructural capacity	Does the city have adequately trained personnel to operate the blockchain system?	☐	☐
	Does the city have adequate and secure backup systems, both digital and manual?	☐	☐
	Does the city population have adequate and equitable access to internet connectivity?	☐	☐
	Can the blockchain system be accessed offline?	☐	☐
	Has the city carried out awareness programs informing and training the residents on usage of the blockchain system?	☐	☐
	Has the city secured reliable and secure data banks?	☐	☐
	Can the blockchain platform be easily integrated with the already existing traditional systems?	☐	☐
	Have adequate funds been secured for the implementation of blockchain, including for additional infrastructure and awareness/training programs?	☐	☐
Governance and Regulatory Frameworks	Is there adequate political will to utilize a decentralized platform for potentially sensitive issues?	☐	☐
	Has the city management mapped out the roles of all the stakeholders, including external ICT partners?	☐	☐
	Have appropriate regulatory frameworks been instituted, including the integration of smart contracts into the traditional legal construct?	☐	☐
	Have appropriate mechanisms to ensure inclusion in access and usage of the blockchain system been put in place?	☐	☐
Reliable Data	Has the city collected all relevant data related to the problem at hand?	☐	☐
	Have appropriate data protection and privacy mechanisms been put in place, including legal considerations?	☐	☐
	Have mechanisms been put in place to ensure community participation in the data collection process to ensure accuracy in data to avoid future conflict?	☐	☐

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