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Moving up the Technology Food Chain: Implementation of Blockchain in Municipalities

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Moving up the Technology Food Chain:
Implementation of Blockchain in Municipalities

> "…it's not bitcoin, the still speculative asset, that should interest you, unless you're a trader. It's about the power and potential of the underlying technological platform."
>
> – Dan and Alex Tapscott, *Blockchain Revolution*[i]

Blockchain technology is most readily associated with Bitcoin, the revolutionary cryptocurrency that has taken the tech world by storm. Blockchain is the underlying technology behind Bitcoin; and since the Bitcoin White Paper was published by Satoshi Nakamoto in 2008, people all around the world have realized new and innovative uses for blockchain. With technology giants like IBM, Samsung and Microsoft increasingly getting involved with and offering blockchain-based, it seems likely that the question has shifted from *whether* blockchain will transform organizations, to when and how it will do so.

In much the same way that you do not need to have in-depth knowledge of the way Microsoft Office works at an operational level in order to implement it successfully, you also do not necessarily need to have a computer sciences-level understanding of how blockchain works in order to appreciate its potential. Our role as legal advisers is to understand the benefits and risks of technology and to have the ability to communicate this knowledge in a helpful, constructive manner as our organizations decide whether they can afford to miss out on the opportunities presented by this emerging technology.

Innovation does not just happen, it requires organizations to make time, and give time, to employees to be inventive. Leaders can organize sessions where a cross-section of departments is represented and the sharing of ideas and problems alike is encouraged. Municipalities need to encourage a bridging of the gap in understanding within their own departments, helping them to understand what blockchain is, why it matters, and why it will likely be relevant to them. Legal departments can assist by having lawyers who focus on Information Technology and are therefore equipped to provide proactive advice and guidance to their clients, rather than just reactive advice when things go wrong. This paper will provide general background on blockchain technology, identify use cases, present benefits and risks, and ultimately encourage thoughtful consideration of how blockchain fits into the future technology roadmap of your municipality.

The Basics: What is Blockchain?

Before transformative effects from blockchain can be achieved in government, participants need to learn the basics of this new architecture. While blockchain is often treated synonymously with Bitcoin, cryptocurrencies are actually only one of many implementations of the underlying technology. Blockchain was developed to support Bitcoin, but it is and has become so much more than that. Early examples of blockchain provided trust between strangers for digital currency transactions, but the participants in a blockchain can be any group of stakeholders or members of a network who seek to eliminate a gap in trust or inefficiency in some type of recordkeeping.[ii] Blockchain is anticipated by some to be as transformational as the Internet has been.

Blockchain is referred to as distributed ledger technology, or DLT. A blockchain records all transactions that take place between the participants in its network. These transactions can be financial, like Bitcoin, but they don't have to be; transactions can also be exchanges of countless types of data. The record is shared, replicated and synchronized among the members of a decentralized network. The blockchain has a set of pre-defined rules for how the ledger is appended by the consensus of the participants in the system. Once a transaction is recorded, it cannot be changed or retracted. The only way to change the blockchain is to add to it. Whereas with a traditional ledger, participants would maintain independent records of transactions that would require reconciliation at the end of a predetermined examination period; with blockchain, the transaction is the record.

Every record in the blockchain (every "block") has a "header" and "content". The header contains a timestamp and unique cryptographic features – hash and a digital signature. The hash is fundamentally what creates the chain – it represents the current state of the blockchain – every single transaction that has been made on the blockchain is represented. The content of each block contains the new transaction(s) that are being appended and now form part of the chain. The very first block is called the genesis block, and it is where the hash originates. As each new transaction is recorded, the hash changes, but each block must link back to the previous block through its hash – thus, forming a chain, as illustrated in Figure 1 below. Including the previous block's hash in the current block incorporates the entire history of the chain into the current block. This makes the database an auditable, immutable history of all transactions in the network, making third party intermediaries such as financial institutions or clearinghouses, unnecessary.

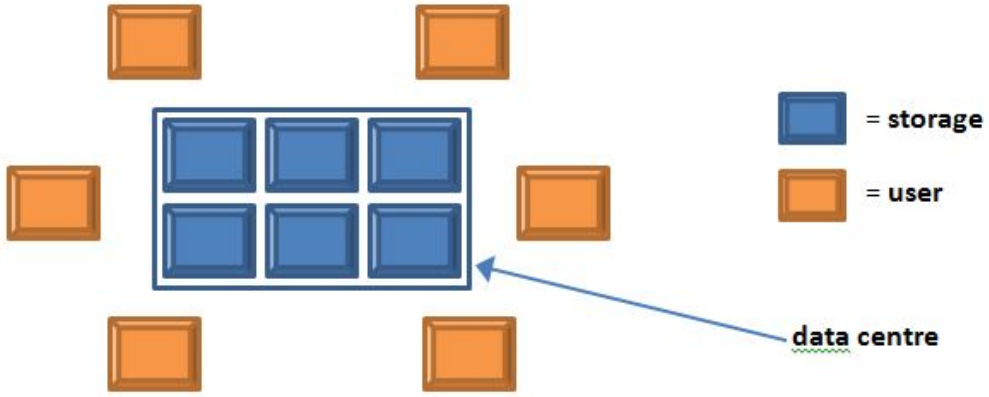
Figure 1



The characteristics and specifics of the protocol of any given Blockchain vary based on numerous factors. Blockchain protocol can be public ("permissionless"), meaning access to the chain is open to anyone; or private ("permissioned"), meaning there is pre-vetting of membership. Often a permissionless blockchain will have a more robust and demanding consensus protocol required to add a block, in order to ensure trust.[iii] This aspect of the protocol becomes important when considering the risks related to privacy, which will be discussed later in this paper.

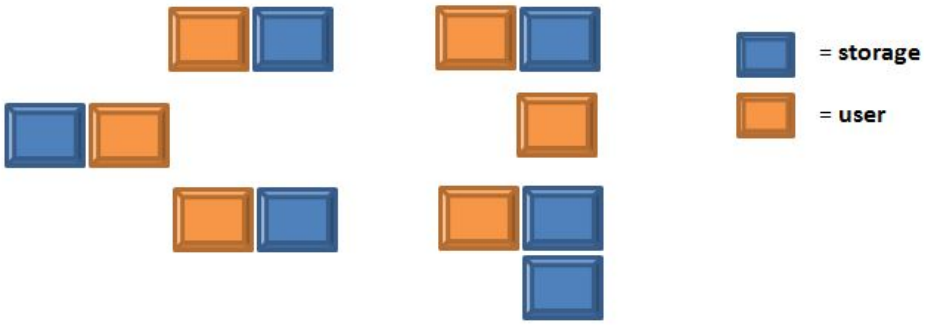
To further explain how blockchain works, I will use the simple example of a phonebook. A phonebook is what we would consider a relational database with structured data. This type of database contains highly organized compilations of data, which are easily searchable using simple, straightforward search engine algorithms. While a database can be stored locally, large databases today typically reside on a server in a data centre. This is referred to as a centralized database, an example of which is shown in Figure 2, below. This type of database is located, maintained and stored in one single location and to access data a user must connect to the server.

Figure 2



The second traditional option is a decentralized database, where data does not have to be (but could be) stored by all participants, and the database of each individual user does not operate any differently than it does in the centralized data centre example. In fact, none of the database users would be aware, simply by using their database, that the data centres were structured one way or the other. A decentralized data centre can look something like Figure 3, below, but it can also have many different variations.

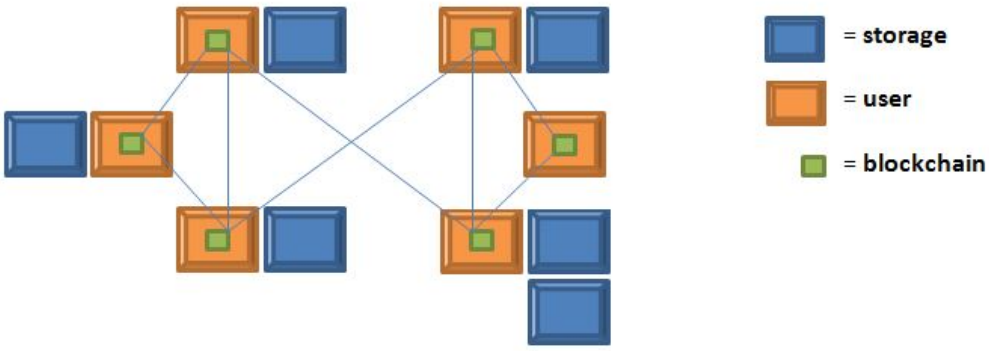
Figure 3



Although these two types of database are different, at their core they are the same. Whether a data centre is centralized or decentralized, it has a central authority – a system administrator. This is a core characteristic of a traditional database. All of the rights to the database are controlled by the organization that creates it, and as the central authority it controls a number of variables or permissions: who can access, who can alter/edit, who can delete.

Blockchain is different because it is distributed; it has no central authority. Every participant in a blockchain has a copy of the database – the blockchain – on their computer. The blockchain is a shared, and continually reconciled, database. A distributed ledger, or database, would look like Figure 4, below.

Figure 4



Returning to my earlier example, take a phonebook and duplicate it thousands of time across a network of computers. The network is designed to regularly update the phonebook and can only be updated if there is a consensus from all of the participants. In the phonebook example, the software could be programmed so that only the owner of any given phone number in the database has the authority to change the number. Once a participant makes the change, it has to be authorized by consensus of the other participants. In order to provide consent, a participant verifies the cryptographic features discussed earlier – the hash and digital signature. Once consensus is achieved, a new block is created and added to the blockchain, which means every database on every participant's device is updated. Once a block is added, it is immutable; blocks are only added, never deleted. This "trustworthy global platform for our transactions" is referred to as the Trust Protocol – "trusted transactions directly between two or more parties, authenticated by mass collaboration and powered by collective self-interests, rather than by large corporations motivated by profit."[iv]

> "…by accelerating transactions and simultaneously lowering their costs, blockchain can help to eliminate layers of redundancy, ease regulatory compliance burdens, introduce recordkeeping efficiency, and generally smooth government operations across a number of areas. Harnessing those advantages and applying them toward public institutions' mission goals provides an opportunity for realizing both agency-specific and whole-of-government benefits that can foster more efficient and effective mission delivery in these challenging times."[v]

To summarize, the key characteristics of blockchain technology are[vi]:

1. <u>Decentralized and distributed</u>
   - Every participant has a full copy of all transactions
   - There is no single point of failure
   - Transactions are verified cryptographically and updated immediately to all participants
2. <u>Irreversible and Immutable</u>
   - The ledger is append-only, meaning no block can be changed once consensus adds it to the chain
   - All transactions are encrypted and include, time, date, participants and hash to previous block
   - Trust is enabled via consensus protocols, cryptography and collective recordkeeping
3. <u>Near real time</u>
   - Transactions are verified and settled within minutes, not days
   - Parties interact directly – no intermediary required

Current Uses

There are many examples of different levels of government as well as private enterprise exploring blockchain use. Land registration by blockchain is being explored on every continent but Antarctica. The use of blockchain technology to enable voting is being tested in New York, Texas, Denmark, Ukraine and Australia, to name a few.[vii]

Walmart has filed a patent for 2 different blockchain-based tools – a marketplace that would enable customers to resell purchased products, as well as a tool for tracking package contents, environmental conditions, and locations. In addition, Walmart has stated that it is ready to use blockchain technology in its live food business in order to improve contamination management and overall transparency.[viii]

Ghana has partnered with BenBen to create a land registry and verification platform that will capture transactions and verify data to allow an automated and trusted property transaction between all parties. Currently, property rights in Ghana are unenforceable in court, and therefore banks will not accept property as collateral. The changes being implemented by BenBen using blockchain will build a land registry and history of transactions that can be verified.[ix]

Korea has partnered with the IT arm of Samsung (Samsug SDS), to develop a blockchain-powered platform that will be used for export customs logistics. The platform is expected to enable the country to streamline and secure document sharing at each step, from goods declarations to delivery, while detecting and preventing the use of forged documents.[x]

Dubai is one of the more progressive participants in blockchain implementation to-date, with a goal of fully-integrating all paper-based transactions to blockchain technology by 2020. The Dubai Blockchain Strategy has three pillars: government efficiency, industry creation and international leadership.[xi] The goal of Dubai's city-wide pilot to introduce blockchain technology is to decrease wasted time, effort and the use of government resources by replacing government services with interoperable blockchains.

Even more forward-thinking than Dubai, is Estonia. Estonia refers to itself as a "digital society". Estonia designed its own blockchain technology, called KSI, which is now used around the world. With digital services already in use, the Government of Estonia introduced blockchain to afford its citizens full control over their personal data. For example, Estonians have the ability to log into the Healthcare Registry records through the use of their digital identities. They can then find out who else has accessed their records and when. Prosecution can

result for anyone, government officials included, who views someone else's records without good reason. [xii]

Potential Use Cases for Municipal Government

Obviously, as set out in the examples above, there are many different potential applications of blockchain technology; and, these are only a few of the numerous instances of use/development. The key prerequisites to look for when considering blockchain as a solution are: i) a need for multiple parties to share data and ii) for all parties to have a common view of the information. If these characteristics do not apply, blockchain is likely not the right solution. Once those prerequisites are met, consideration of other characteristics of the project can be evaluated to see if blockchain is the right fit, things such as: the need for multiple parties to be able to update the data; the need for trust that the actions recorded are valid; and removal of dependency on intermediaries.

Smart Contracts

Smart contracts are not really contracts in the legal sense, in that there is nothing that needs to be complied with or upheld by them. Instead, smart contracts are a set of self-executing business rules that determine how two participants transact on a blockchain. A smart contract puts paper processes into a standard format so they can be executed on the blockchain. To enable a smart contract, code is included in the blockchain that can test for specific conditions to be met and, once met, act accordingly; essentially, "if X, then Y" actions are built into the transaction, fostering automation and enforcement.[xiii] A smart contract can be established in a supply chain that automatically executes an organization's procure-to-pay process from end-to-end. In other words, the contract itself takes care of purchase orders, it knows the precise number of units required, at what time and where, and it secures the best price from the best supplier. Once the product is delivered, the smart contract executes to make payment right away. Because automatic matches are made between purchase orders, goods received, and invoices, the blockchain establishes that there are no disputes as a result of missing documents or human error. This type of solution eliminates the need for a number of expensive and often inefficient intermediaries – financial institutions, internal approvers, purchasing agents, goods-verifiers, etc. The result is a faster process with complete transparency at each stage of the transaction.

> With blockchain, we can imagine a world in which contracts are embedded in digital code and stored in transparent, shared databases, where they are protected from deletion, tampering and revision. In the

> world every agreement, every process, every task and every payment would have a digital record and signature that could be identified, validated, stored and shared. Intermediaries like lawyers, brokers and bankers might no longer be necessary. Individuals, organizations, machines and algorithms would freely transact and interact with one another with little friction. This is the immense potential of blockchain.[xiv]

One example of a smart contract type blockchain use case for municipalities is smart contract dealing with office supplies. This use case could be implemented in any office in the world, whether government or private industry. Imagine an office where Internet of Things devices are designed to track office supply levels. A smart contract utilizes these devices to execute and order supplies when needed. The entire supply chain is executed without manual intervention, all based on actual need. The ordering would be more economical because the smart contract would only be enabled to order supplies that are necessary to the functioning of the organization; personal requests and desires would be removed from the equation. The contract can be established with one supplier who will serve every department so that shipping can be coordinated to save time, money and reduce the carbon footprint.

Voting

Governments around the world are investigating use cases for blockchain-based voting platforms. These platforms are said to be able to achieve "secure, anonymous and unique voting in a decentralised and digitized manner by removing inefficiencies and complexities that characterise other forms of voting."[xv] One basic concept of blockchain-based voting is to have citizens cast their vote via a token that would be deposited in their account. The ballot would be cast by sending the token to a specific address (the address of the candidate the person wants to vote for). In actuality, there would be a user interface that would do all of this, but would hide the process of sending the token from the voter and instead have a simple interface where they could click to select a candidate. The process is actually fairly complicated, however, because voter identity has to be verified and anonymity must be maintained; but the concept is there and companies are working towards viable solutions.[xvi]

Registries

Although not often controlled by local levels of government, registries are one of the buzzwords when it comes to ideas on how to utilize blockchain in government

applications. Business registries, where corporations can be managed from registration to dissolution, all while giving the public a 360-view in a trustworthy manner; land registries, which in developed nations can eliminate cost and increase efficiency and in underdeveloped countries can help to codify land ownership; and civil registries for everything from birth to death.[xvii]

Infrastructure

There are a number of potential uses for blockchain when it comes to infrastructure management. **Renewable energy** invested in by individual citizens can be used to supply day-to day personal use, with the remainder being sold back to the grid on a blockchain-based system. Smart tracking meters can be combined with smart contracts to automate water supply management in **water and wastewater** systems ensuring an efficient distribution of water. **Waste management** can be revolutionized through the use of smart sensors that can track levels of waste and provide more efficient and well-aligned strategies to dealing with waste.[xviii]

Challenges & Limitations

The very first question, even before identifying the potential risks posed by contracting for and implementing blockchain technology, should be this: Have you identified who or which business function owns responsibility for managing the implications and exploring the potential of disruptive technologies such as blockchain? Especially when it comes to cutting edge technology, it is important to make sure that there is an ultimate decision maker, or group thereof, and that they are identified and educated. Technology offers amazing opportunities in innovation, cost savings, and efficiency. People are going to want to use technology to make their lives better; but it is important that there is oversight on each implementation, to ensure that the risk tolerance of the organization is appropriate and consistently applied.

Security

As with any technology solution, security should be at the forefront when considering how and what to implement. The data that will be stored on the system will drive the rigour with which you evaluate security. At its core, blockchain is a ledger system. While the technology is complicated, the basic idea is not. Blockchain offers a way to validate information reliably and securely without allowing for the ability to edit or delete previous entries. It is essentially a creation of trust.[xix] Where the trust comes from can differ, depending on what

type of blockchain protocol is employed. As with anything, whichever blockchain system you choose, it will only be as strong as its weakest link. While there is much excitement about the security features of blockchain, it should not be taken for granted. Any potential system should undergo a security and privacy assessment, without any preconceived notion of inherent security just because it is blockchain. Blockchain solutions can be decentralized, but they aren't always. Where the systems differ, so too can their levels of security.

In a permissioned (private) blockchain, there will be a central authority that controls who has write permissions to the system. In this way, trust will come from the same place it often does with a typical database structure. If the system that houses the blockchain uses single-factor authentication, the user will require a certain username and password, for example, to be able to access the system and thus, the blockchain. These identifying features will be enough to tell the blockchain to trust this person because it will know that the person in question has the authority to access it. "Private blockchains are a way of taking advantage of blockchain technology by setting up groups and participants who can verify transactions internally."[xx] The risk of a security breach on this type of system is essentially the same as any other centralized system; if one user is hacked the entire system could be impacted.

In a public blockchain, such as Bitcoin, the decentralized nature of the system requires different authentication to create trust. Public blockchain protocols are based on Proof of Work (PoW) consensus algorithms that are open source and not permissioned. In the Bitcoin protocol, this is a mathematical PoW referred to as mining. The PoW in Bitcoin is very hard to generate because there is no way to create them other than by trying billions of calculations per second. This requirement makes it very difficult for any one participant to consecutively add new blocks of transactions into the blockchain.[xxi] This creates a different kind of trust, because the trust does not reside in a particular person/their identity, it comes from the verification of many users that the block in question is verified.

All this is to say that when contemplating a blockchain solution, the same steps must be taken to assure yourself and the organization with respect to security as you would take with any other technology solution: understand who has access, what kinds of access and where the potential for a breach is.

Privacy

An interesting issue of potential conflict has been raised with respect to blockchain and privacy law compliance, specifically in relation to the new General Data Protection Regulation ("GDPR") requirements in the EU. While one

of the significant features of blockchain is the general immutability of its data, one of the most discussed features of the GDPR is its "erasure" right. Article 17 of the GDPR requires that companies erase the personal data of individuals when they ask to be "forgotten". Because GDPR requirements are new, there is a lack of interpretation about how exactly they will be interpreted and enforced. There is no definition of "erase" in the GDPR, and "personal data" is very broadly defined; combine the two and some practitioners and scholars have expressed the opinion that an "individual's publicly available cryptocurrency wallet address would be considered personal data under the GDPR", and thus, subject to the erasure right.[xxii] Only time will tell how all of this will play out, but certainly on the fact of it the technology appears to be in conflict with the regulation.

While the GDPR likely has limited applicability to the activities of a Canadian municipality, it is important to note that the federal government is giving thought to updating Canada's privacy laws. There have been some indications that these changes may come in the form of an alignment to GDPR requirements and penalties.[xxiii] These changes could have a trickle down effect on municipal privacy laws.

The way we currently deal with data and the sharing of information certainly needs improvement.

> When we share vital information such as our name, date of birth, address, and social security number, that sensitive data is passed to third-party companies that require it. This creates two additional problems: We have to repeatedly fill out forms every time we interact with a new organization, and the firms that make copies and store our information in centralized databases are easy targets for hackers.[xxiv]

The problem is, it is unclear whether blockchain technology will actually improve this scenario. As with most things, the blockchain is only as strong as its weakest link and it will be imperative that municipalities engage with compliant, trusted vendors, and have in-house legal and information technology expertise, who can identify those weak links in any given implementation.

Contractual Considerations

One of the biggest challenges for implementing blockchain in a municipal organization will be determining what the governance model will be that applies to a blockchain-based project. For example, what are the rights of different participants, what are their obligations, how are conflicts to be resolved, and how is liability handled? It is important to take the time now to carefully draft and

evaluate policies established around blockchain technology to ensure that there are no unintended consequences that ultimately end up thwarting innovation and development.[xxv] The establishment of master plans that address these types of issues is a good starting point.

Power

In order to make it run at decent speed, blockchain requires a large amount of computer processing power, which in turn requires a large amount of cooling and thus, electricity. Cryptocurrencies in particular create a large energy demand that is a significant drain on the world's electricity resources. As discussed above, inn the Bitcoin blockchain, blocks are added to the chain when they are authenticated. Part of the authentication process is the solving of a complex mathematical puzzle known as the "nonce". This is accomplished through a massive computational trial and error process, which requires a large amount of processing power.[xxvi] There are estimates that, "by 2019, the Bitcoin network alone will require more energy than the entire United States currently uses and that by February 2020 it will use as much electricity as the entire world does today."[xxvii] However, even with those predictions, experts consider this a solvable problem, aided by the fact that computing power becomes more efficient by the day. Municipalities will need to be aware of the possible infrastructure requirements of implementing blockchain. If implementing a system in-house (as opposed to a Blockchain as a Service (BaaS) type system), processing power will be needed to ensure the system runs efficiently. Cooling of the extra servers required is another consideration not to be overlooked.

Strategies for Moving Forward

First and foremost, start small. Single-use applications minimize risk because they aren't new and they involve little to no coordination with third parties. The use of (private) blockchain internally for applications like managing physical and digital assets, recording internal transactions, and verifying identities are just a few examples of starting points. Organizations that are struggling to reconcile multiple internal databases might benefit from combining them onto blockchain technology. Testing these single-use applications will help employees to develop the skills they need to move towards more advanced applications, as well as for organizations to develop comprehensive plans on for larger implementations that are enterprise-wide.[xxviii]

Education and engagement of citizens will be key to the success of emerging technology implementation. The Infrastructure Canada Smart Cities Challenge

that is currently underway puts a large focus on community engagement. “Smart cities should aim to engage their citizens, by offering them a place where they want to live, love, grow, learn and care. And in doing so giving them the will to change and the will to act.”[xxix] As technology solutions like blockchain become more pervasive in society, it will be vital to ensure that all citizens are able to continue to be active participants in society.

Understanding the potential impact of blockchain and the best use cases for your organization is as much an exercise in thinking through transformative business models as it is about the actual technology solutions. When developing the Dubai Blockchain Strategy, Dubai held 40 blockchain related workshops. Thirty different government bodies were in attendance at these workshops, which were used to determine the effectiveness of performing transactions through blockchain, as well as to create sound blockchain policies prior to implementation of the technology. Industry creation is another of the pillars of the Dubai Blockchain Strategy. Dubai sought to allow citizens and business partners to develop new businesses leveraging blockchain technology. [xxx] While places like Dubai and Estonia have been focused on technology and becoming digital societies, for most municipalities this will not be the case. To ensure a successful project the focus should be on the problem you are trying to solve, or the result you wish to see, rather than the technology solution. Agile policy formation is something all governments should start getting comfortable with as technology development in the private sector continues to move faster than policy. Formulating digital master plans is essential so that there is a foundation to fall back on as new technologies enter the mix. Organizations should also make a conscious decision as to what role they intend to play when it comes to technology – will your organization follow a path, or forge one? If innovation is the chosen course, recognition that sometimes things go wrong will be essential; and when they do, it is important to stick to the principles established at the outset, learn from those mistakes and talk about them openly. While it may be premature for municipalities to start making significant investments in blockchain technology, developing the required foundations for this platform, including skills, standards and best practices, is still forward thinking and a worthwhile objective.

[i] Don Tapscott and Alex Tapscott, *Blockchain Revolution*, (Toronto: Penguin Canada, 2016), at 9 [*Blockchain Revolution*].

[ii] Deloitte University Press, *Will blockchain transform the public sector? Blockchain basics for government*, 2017, accessed online at: https://www2.deloitte.com/content/dam/insights /us/articles /4185_blockchain-public-sector/DUP_will-blockchain-transform-public-sector.pdf, at 6 [*Deloitte*].

[iii] *Deloitte*, *supra* note ii.

[iv] *Blockchain Revolution*, *supra* note i, at 5.

[v] *Deloitte*, *supra* note ii, at 8.

[vi] *Ibid*.

[vii] *Ibid* at 2.

[viii] "Walmart Files Patent for Blockchain-Based Customer Marketplace", *BlockchainCan* (May 23, 2018), online: https://blockchaincan.com/walmart-files-patent-blockchain-based-customer-marketplace/).

[ix] "Blockchain Powered Land Registry in Ghana with BenBen", *BigchainBD*, online: https://www.bigchaindb.com/usecases/government/benben/

[x] Ana Alexandre, "Korea Customs Service Partners with Samsung SDS to Build Blockchain Customs Platform" *Coin Telegraph* (September 15, 2018), online: https://cointelegraph.com/ news/korea-customs-service-partners-with-samsung-sds-to-build-blockchain-customs-platform.

[xi] "Dubai is Ready to Set a Record of Being the First Blockchain-powered City in the World" *SmartCity.Press* (February 5, 2018), online: https://www.smartcity.press/dubai-blockchain-strategy-2020/ [*Dubai is ready*.

[xii] E-estonia, accessed online at: https://e-estonia.com.

[xiii] *Deloitte*, *supra* note ii at 9.

[xiv]Marco Iansiti and Karim R. Lakhani, "The Truth About Blockchain" *Harvard Business Review* (January – February 2017), online: https://enterprisersproject.com/sites/default/files/ the_truth_about_blockchain.pdf, at 4 [*The Truth About Blockchain*].

[xv] "Blockchain: The next innovation to make our cities smarter" *PricewaterhouseCoopers Private Limited* (January 2018), online: https://www.pwc.in/assets/pdfs/publications/2018/blockchain-the-next-innovation-to-make-our-cities-smarter.pdf [*Blockchain: The next innovation*] at 24.

[xvi] Bennett Garner, "How Blockchain Voting Works and Why We Need It", *Coin Central* (April 13, 2018), online: https://coincentral.com/how-blockchain-voting-works-why-we-need-it/.

[xvii] *Blockchain: The next innovation*, *supra* note xv at 26.

[xviii] *Ibid* at 27-29.

[xix] Tim Wilbur, "Can you trust blockchain?", *Canadian Lawyer Magazine* (May 14, 2018) online: https://www.canadianlawyermag.com/author/tim-wilbur/can-you-trust-blockchain-15701/.

[xx] "Blockchains & Distributed Ledger Technologies", *BlockchainHub*, online: https://blockchainhub.net/blockchains-and-distributed-ledger-technologies-in-general/.

[xxi] Bitcoin, accessed online at: https://bitcoin.org.

[xxii] Nicole Kramer, "Blockchain, Personal Data and the GDPR Right to be Forgotten", *Toronto Lawyers Association* (April 17, 2018), online: https://www.blockchainandthelaw.com/2018/04/ blockchain-personal-data-and-the-gdpr-right-to-be-forgotten/.

[xxiii] *Towards Privacy by Design: Review of the Personal Information Protection and Electronic Documents Act*. Report of the Standing Committee on Access to Information, Privacy and Ethics. Bob Zimmer, chair. Accessed online at: http://www.ourcommons.ca/Content/Committee/421/ ETHI/ Reports/RP9690701/ ethirp12/ethirp12-e.pdf.

[xxiv] Shane Owen, "Worried About Your Data Privacy? Blockchain Could Help" *Fortune* (June 27, 2018) onlinet: http://fortune.com/2018/06/27/facebook-data-privacy-blockchain/.

[xxv] Lucas Mearian, "IBM sees blockchain as ready for government use", *Computer World* (February 14, 2018), online: https://www.computerworld.com/article/3254202/blockchain/ibm-sees-blockchain-as-ready-for-government-use.html.

[xxvi] "Optimizing Data Centers to Meet the Needs of Cryptocurrency Miners" *Mintz* (April 17, 2018), online: https://www.mintz.com/insights-center/viewpoints/2018-04-optimizing-data-centers-meet-needs-cryptocurrency-miners.

[xxvii] Gil Perez et al, "The Blockchain Solution" *Digitalist Magazine* (February 21, 2018) accessed online: https://www.digitalistmag.com/executive-research/the-blockchain-solution.

[xxviii] *The Truth About Blockchain*, *supra* note xiv, 10.

[xxix] Fran Van Geertruyden, "Smart cities: citizens' engagement at least as important as smart technology" *Medium* (June 20, 2018), online: https://medium.com/databrokerdao/smart-cities-citizens-engagement-at-least-as-important-as-smart-technology-4eabcf5ca04b

[xxx] *Dubai is ready*, *supra* note xi.