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Blockchain: The next innovation to make our cities smarter





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Foreword



Dr Sanjaya Baru
Secretary General
FICCI

I am happy to share with you the FICCI- PwC report on ‘Blockchain: the next innovation to make our cities smarter’ to be released at the Smart Cities Summit organized by Federation of Indian Chambers of Commerce and Industry.

The Smart Cities Summit aims to deliberate upon the upcoming business opportunities in the cities, challenges of project execution, adoption of innovative technologies and necessary policy interventions for the Smart Cities Mission.

The 100 Smart Cities Mission (SCM) is one of the key initiatives taken by the Government of India to change the urban ecosystem in India. With 90 cities already selected under the mission and about 2800 SCM projects rolled out in the last 3 years, active engagement with the relevant stakeholders is very critical at this stage.

To realize the objectives of SCM, cities are being planned in a way that fosters clean environment, nestles smart infrastructure and facilitates accessibility for the vulnerable groups. Additionally, adopting new technologies remain central to the implementation of this key initiative as it addresses the key concern points in the area of water management, energy saving, urban mobility, housing and accessibility. In view of the same, it becomes imperative to explore the possibility of adopting dynamic and efficient technologies for making our cities smarter.

The report provides a broad understanding of the current urban challenges being tackled through smart cities. The report highlights one of the new technology breakthroughs—blockchain and analyses its transformative potential in making our cities smarter. Further, it explores multiple uses of the blockchain technology in the smart city domain and explains the prerequisites for the adoption of a blockchain-based solution and the way forward.

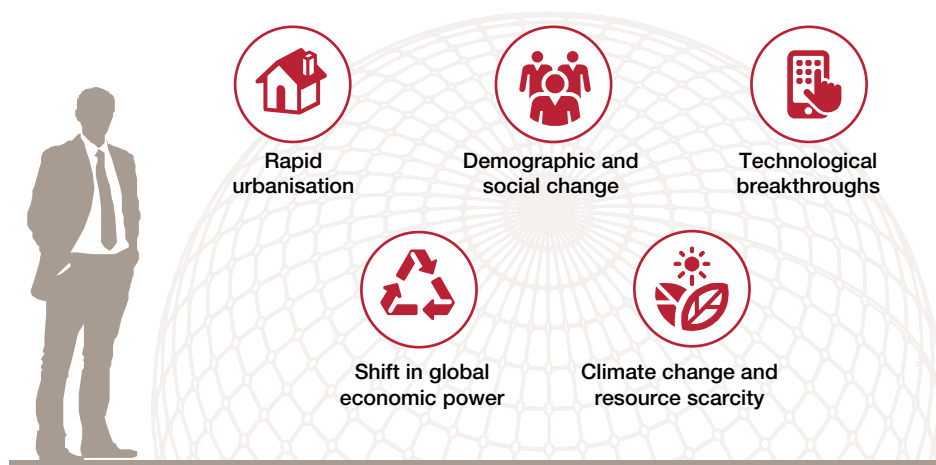
We hope you will find this report useful. Your suggestions and feedback are welcome.

Preface

Both governments and private organisations need to plan for the future and have an insight into the changes that can occur in the world. Today, they have an opportunity to dig deep, search for innovative solutions, inspire positive growth, gain economic prosperity, develop stronger communities and healthier people, and provide for greater social mobility. Foresight is essential for governments and enterprises to know what they should be working towards and why.

At PwC, we believe that there are five global shifts which are reshaping the world we live in. These shifts have a major influence today and will become even more important in the coming decades:

Five global shifts



This paper touches upon two of the five megatrends—rapid urbanisation and technological breakthroughs. Today, more than half the world’s population lives in urban areas¹. Rapid urbanisation focuses on opportunities presented by this urban transition to create emerging cities that act as powerful and inclusive development tools. Technology breakthroughs, on the other hand, deal with the digital revolution which now has a direct or obvious impact in all spheres.

The purpose of this report is to understand one of the new technology breakthroughs—namely blockchain—and analyse how it can be utilised for making cities smarter. It studies various areas of a smart city and identifies those areas where blockchain innovation can be used to enhance our cities and provide for better liveability and economic development.

¹ PwC UK. (n.d.). Rapid urbanization. Retrieved from <https://www.pwc.co.uk/issues/megatrends/rapid-urbanisation.html#1> (last accessed on 4 January 2018)

Executive summary



Neel Ratan

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Trust is a fundamental part of the value chain in our world. We establish trust through a wide variety of intermediaries that exist with the sole purpose of aggregating and validating information. Blockchain technology has now made it possible to redefine the enterprise of 'trust' by making information inherently trustworthy. The blockchain also promises to deliver IT solutions which are more robust, resilient, tamper-proof, efficient and transparent. But can it make our cities smarter?

We live in a world where information is generated and exchanged at a scale that could not have been imagined a few decades ago. Information is processed and made available to consumers at their fingertips. In a world where information increases exponentially over mediums that are easily accessible, its reliability is of paramount importance. Currently, in order to make information reliable and facilitate transactions, we depend on a large number of intermediaries that authenticate the information to establish 'trust' between transacting parties. Authentication of financial transactions by banks is an example of how the world is built around creating a framework that can be used to establish trust.

These intermediaries of trust play a fundamental role in the manner that we operate. It is ironic that, in a day and age when information is so easily available, these intermediaries exist solely because of a fundamental 'lack of faith'.

A blockchain is a distributed ledger technology that stores information across multiple systems securely to enable peer-to-peer transactions by creating a trustworthy source of 'truth' disintermediating the so-called 'intermediaries of trust'. Verification by virtue of secured distributed storage brings about a paradigm shift in the way we establish trust and has far-reaching implications.

Blockchain is poised to revolutionise how we perform any kind of transaction and will impact everyone (banking, power, education, healthcare, etc.). The public sector is no exception.

The government and public sector have a pressing need for complete, secure, authentic and

trustworthy information exchange across various fields. Blockchain technology is emerging as a tool for governments around the world to redefine the framework under which information can be used for transactional purposes. Use cases such as blockchain-based voting, supply chain visibility and citizen registration can have a very high impact on some of the current systemic problems such as inefficiency, data security, lack of transparency and corruption.

Smart cities are one of the focus areas of many governments across the globe. Many countries have created strategies for transforming their cities into smart cities in order to fully utilise the potential opportunities arising from urbanisation. Smart cities enable operational efficiencies, maximise environmental sustainability efforts and create new citizen services. India launched its Smart Cities Mission with the aim of developing 100 smart cities. The government defined the features of a smart city, many of which can potentially be implemented on a blockchain for enhanced security, immutability, resilience and transparency.

This paper focuses on providing a broad understanding of the current urban challenges being tackled through smart cities. Subsequently, it describes the concepts of blockchain technology and analyses its transformative potential in making our cities smarter. The paper also explores multiple use cases for blockchain in the smart city domain. Finally, it briefly explains the prerequisites for the adoption of a blockchain-based solution and the way forward.



Introduction

Basic amenities such as a clean environment, water, energy and infrastructure are required by all citizens around the globe. But the demand for these basic amenities is growing at a rapid pace due to an ever-increasing population. Citizens are moving towards urban areas for easy access to these basic amenities and other facilities such as employment opportunities, health care and other facilities. Thus, urbanisation is increasing rapidly as urban cities promise improved liveability and a higher standard of living. It is estimated that around 1.5 million people are added to the global urban population every week.² Increasing urbanisation is straining available city resources such as space and infrastructure.³

The story is no different in India where urbanisation is high and leads to environmental and social challenges. Cities are characterised by strained resources, which leads to a shortage of power, insufficient water supply, poor government services, unaffordable cost of living, inadequate public transportation, frequent traffic jams,

pollution, depleting natural resources, etc.

These urban challenges are forcing cities across the globe and in India to become smarter. Governments across the globe have created or are creating strategies for 'smart city' transformation to cater to their citizens effectively and efficiently. Smarter cities promise to improve operational efficiencies, maximise environmental sustainability efforts and create new citizen services.

The smart city concept can be looked upon as a framework for implementing a vision of advanced and modern urbanisation. Smart cities leverage technology and utilise existing and planned infrastructure investments to provide a higher quality of living to residents and a conducive investment climate for businesses, and to maximise resource utilisation and transparency for governments. Smart cities can be considered an organic integration of systems, IT infrastructure, physical infrastructure, and social and business infrastructure. These systems work collectively so as to generate intelligent and actionable information for decision makers.⁴



² PwC UK. (n.d.). Rapid urbanization. Retrieved from <https://www.pwc.co.uk/issues/megatrends/rapid-urbanisation.html#1> (last accessed on 4 January 2018)

³ PwC. (2015). How smart are our cities? Retrieved from https://www.pwc.in/assets/pdfs/publications/2015/how_smart_are_our_cities.pdf (last accessed on 4 January 2018)

⁴ PwC and FICCI. (2015). India: Surging to a smarter future. Retrieved from <https://www.pwc.in/assets/pdfs/publications/2015/india-surging-to-a-smarter-future.pdf> (last accessed on 4 January 2018)



In India, the Smart Cities Mission was launched on 25 June 2015 with the aim of creating 100 smart cities. The objective, as defined by the Ministry of Housing and Urban Affairs (MoHUA), is ‘to promote sustainable and inclusive cities that provide core infrastructure and give a decent quality of life to its citizens, a clean and sustainable environment and application of “Smart” Solutions’.⁵ The following are the key areas of a smart city as defined by the MoHUA:

Citizen participation	Identity and culture	Economy and employment
Health	Education	Mixed use
Compactness	Open spaces	Housing and inclusiveness
Transportation and mobility	Walkable	IT connectivity
Intelligent government services	Energy supply	Energy source
Energy efficiency	Underground electric wiring	Water supply
Waste water management	Water quality	Air quality
Sanitation	Waste management	Safety



Combating the challenges of rapid urbanisation requires technologies and planning approaches that challenge the traditional city development models. Innovation and technology enable a ‘smarter city’ to become more liveable, sustainable and productive.⁶ These developments are fundamentally changing the way citizens, business and governments interact with each other. One such innovative technology which can make cities smarter is blockchain.

Blockchain technology has the potential to disrupt many of the areas of smart cities identified by the MoHUA. It can be used to make the technology initiatives of a smart city more secure, transparent, efficient and resilient. It can also ‘enable’ our cities operate more efficiently, thereby increasing productivity and economic growth.

⁵ Government of India. (n.d.). Improving lives: Urban infrastructure. Make in India website. Retrieved from <http://www.makeinindia.com/article/-/v/improving-lives-urban-infrastructure> (last accessed on 4 January 2018)

⁶ PwC UK. (n.d.). Rapid urbanization. Retrieved from <https://www.pwc.co.uk/issues/megatrends/rapid-urbanisation.html#1> (last accessed on 4 January 2018)

What is a blockchain?

A blockchain is a peer-to-peer distributed ledger that is cryptographically secure, append-only, immutable, and updatable only via consensus or agreement among peers.⁷

Blockchain is a digital, decentralised (distributed) ledger that keeps a record of all transactions that take place across a peer-to-peer network. It is an interlinked and continuously expanding list of records stored securely across a number of interconnected systems. This makes blockchain technology resilient since the network has no single point of vulnerability. Additionally, each 'block' is uniquely connected to the previous blocks via a digital signature which means that making a change to a record without disturbing the previous records in the chain is not possible, thus rendering the information tamper-proof.

The key innovation in blockchain technology is that it allows its participant to transfer assets across the Internet without the need for a centralised third party.

Blockchain technology was developed as the underlying technology behind the cryptocurrency called bitcoin. The aftermath of the 2008 subprime crisis reduced trust in the existing financial system.

This is when a person or a group of people called Satoshi Nakamoto wrote a white paper containing the 'bitcoin protocol' which used a distributed ledger and consensus building to compute algorithms. The bitcoin protocol was written to disintermediate traditional financial intermediaries as a means of facilitating direct P2P transactions.

Since the birth of the Internet, there have been efforts to create virtual currencies, but those efforts failed due to the 'double spend' problem, namely the risk that a digital asset such as a currency can be spent twice.⁸ The current solution to eliminate the double spend problem is through the introduction of 'intermediaries of trust' such as banks. But the application of blockchain technology makes it possible to solve the fundamental problem of double spending without the need for such intermediaries of trust, thereby facilitating the transfer of assets such as virtual currencies over the Internet securely. This concept can be extended to non-currency related areas and that's the promise of blockchain technology.



⁷ Bashir, I. (2017). Mastering blockchain. Mumbai: Packt Publishing.

⁸ Investopedia. (n.d.). Definition of double-spending. Retrieved from <https://www.investopedia.com/terms/d/doublespending.asp> (last accessed on 4 January 2018)

4.1. The blockchain advantage

Blockchain is a distributed network that stores information in tamper-proof form which can only be appended but not modified by valid 'users'. In order to understand the full potential of the blockchain, one needs to understand the basic attributes of blockchain which makes this technology unique:



Shared ledger

It is an append-only distributed system shared across the business network, which makes the system resilient by eliminating a 'single point of failure'.



Consensus

A transaction is only committed when all parties agree to a network verified transaction.



Provenance

The entire history of an asset is available over a blockchain.



Immutability

Records are indelible and cannot be tampered with once committed to the shared ledger, thereby making all information trustworthy.



Finality

Once a transaction is completed over a blockchain, it can never be reverted.



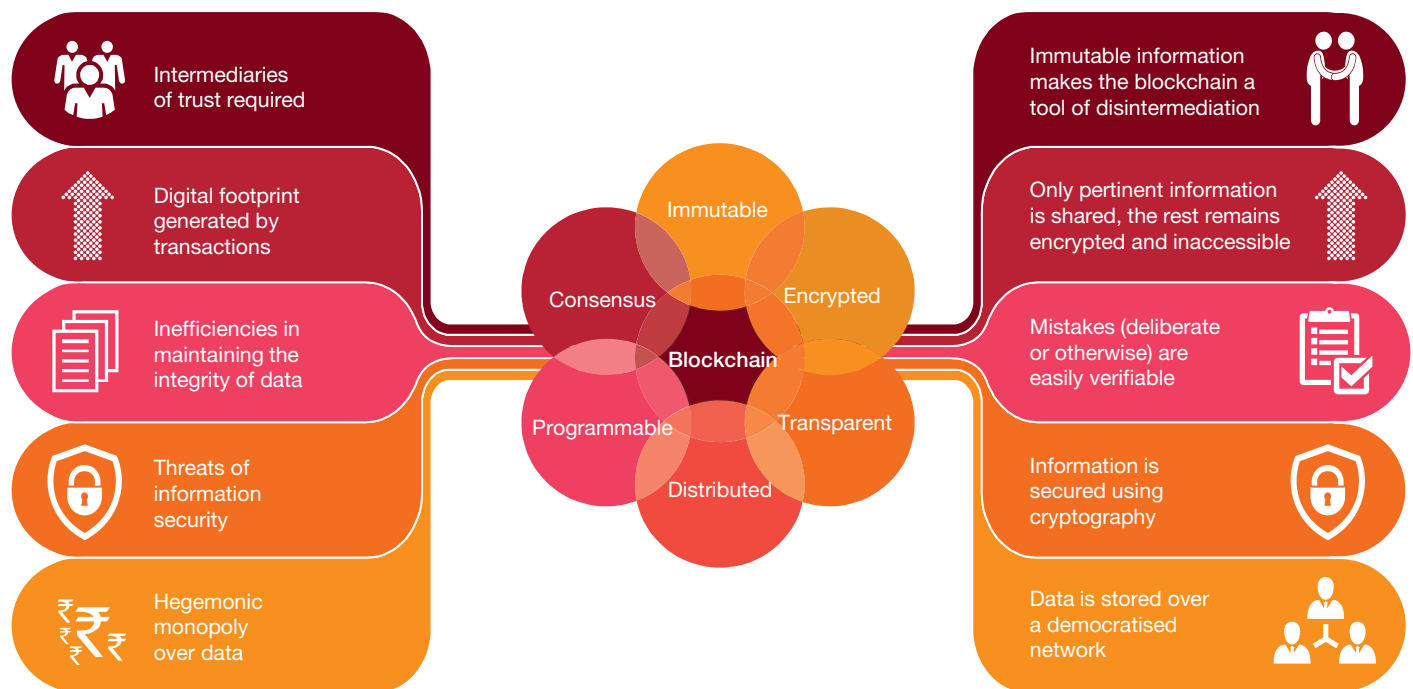
Smart contracts

Code is built within a blockchain that computers/nodes execute based on a triggering event. Essentially, an 'if this then that' statement which can be auto-executed.



The blockchain holds the potential to disrupt any form of transaction that requires information to be trusted. This means that all intermediaries of trust, as they exist today, are exposed to being disrupted in some form with the advent of blockchain technology. The figure below shows how blockchain technology is resolving problems with the way information-related transactions occur today. The boxes on the left illustrate key issues, while those on the right depict how blockchain technology helps address them.

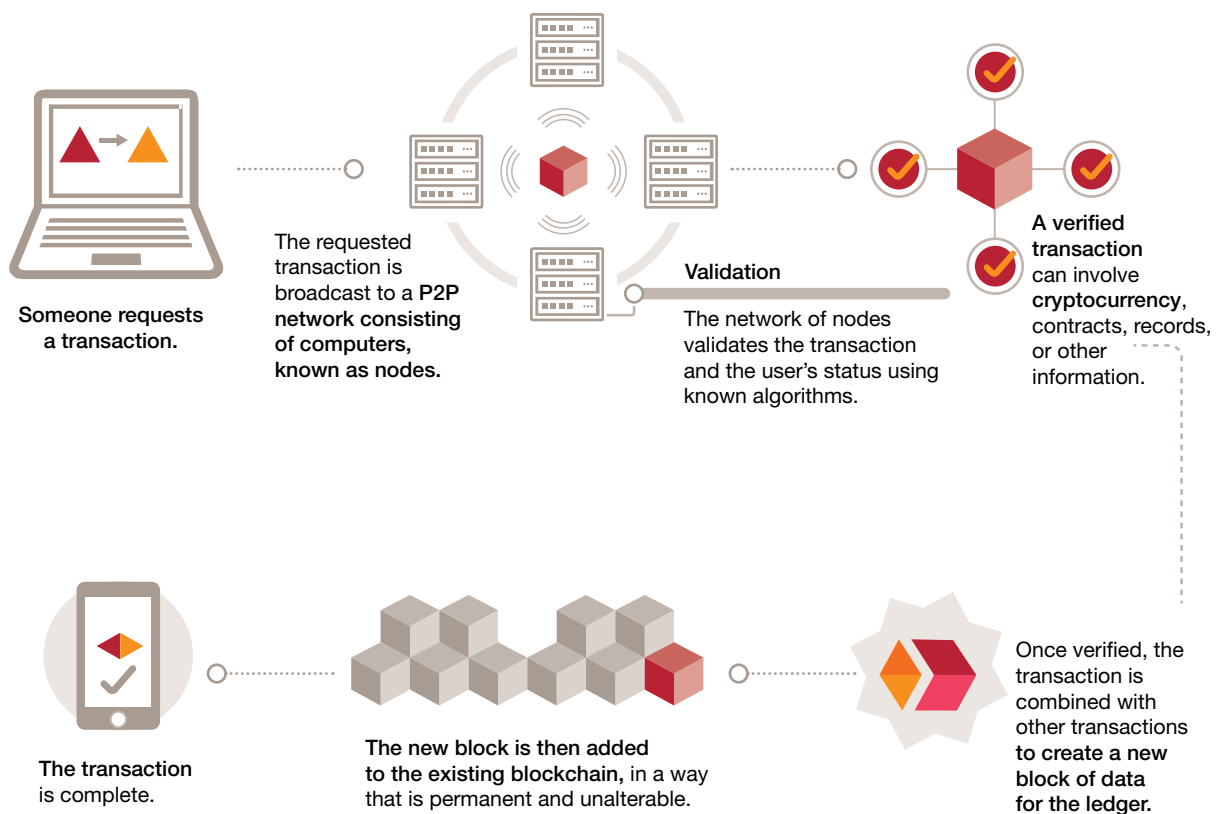
The blockchain advantage



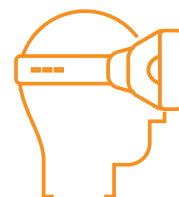
4.2. How does blockchain work?

Blockchain works by validating transactions through a distributed network in order to create a permanent, verified and unalterable ledger of information.⁹

How blockchain works



⁹ PwC US. (n.d.). Making sense of bitcoin, cryptocurrency, and blockchain. Retrieved from <https://www.pwc.com/us/en/financial-services/fintech/bitcoin-blockchain-cryptocurrency.html> (last accessed on 4 January 2018)



4.3. Types of blockchains: Public and private

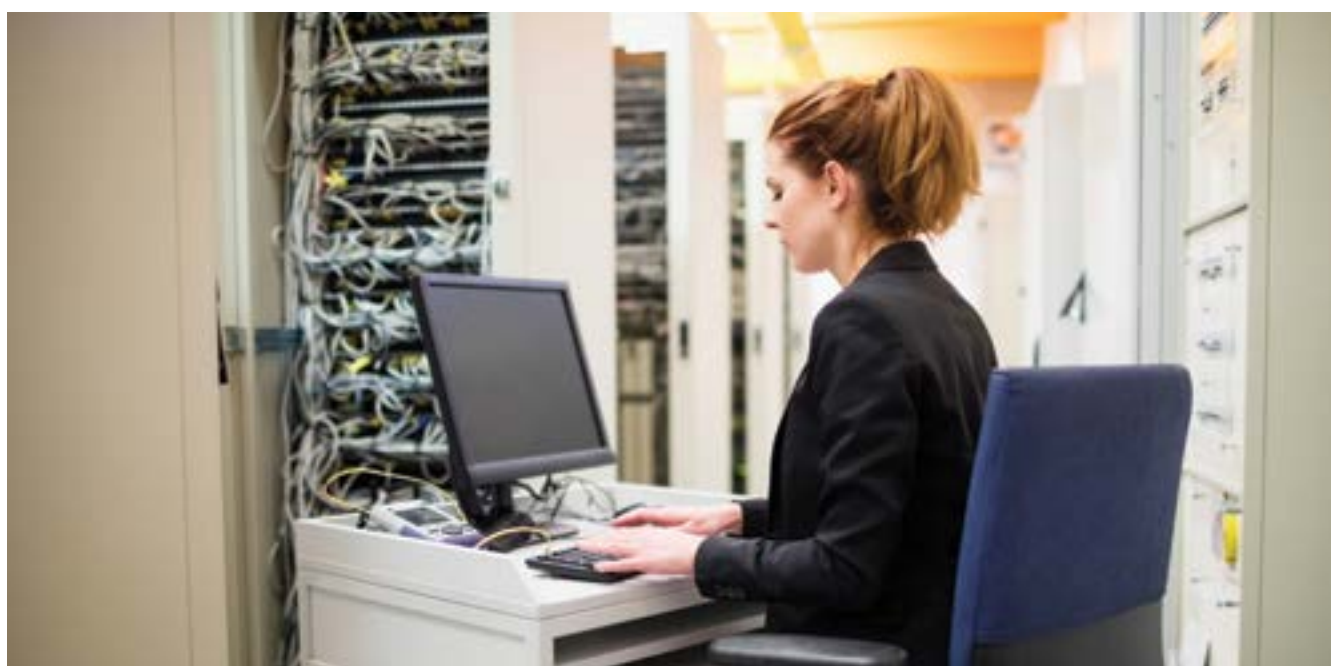
A blockchain network can either be public or private based on who is authorised to participate. The essential difference between a public and private blockchain is that one operates in a decentralised open environment where there are no restrictions on the number of people joining the network, while the other operates within the confines defined by a controlling entity. A simple analogy is the difference between the Internet and the intranet. While the inherent technology for networked computers remains the same, there is a big difference between the dynamics and utility associated with a closed network (such as a home network) and an open network (such as the Internet).

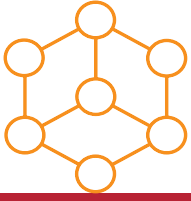
In reality, this difference plays out based on how 'nodes' are incentivised to remain a part of the network. The key idea here is that in a public blockchain, the consensus mechanism is based around rewarding each individual participant to remain a part of the network. In a private blockchain, the need for creating this incentive does not exist.

The democratised nature of a true transparent public ledger might not be of utility to an organisation or an

enterprise network as the parties are known, and a level of understanding exists about which members can participate in the network and on what type of transactions. The general consensus is that while public blockchains work well for certain applications such as cryptocurrency-based transactions (bitcoin), the larger application of blockchain technology as an enterprise solution would only be possible with the increased regulatory control associated with a private blockchain ecosystem.

It is important to note that the technology is still nascent. As a result, its different applications are evolving continuously and iteratively. The question of public vs private blockchain networks may eventually get addressed by an ecosystem where a number of private blockchains interact with one another over a publicly distributed network. The answer to the question may not be a simple choice between the binary options available; it may very well lie in a shared ecosystem where both public and private blockchains function symbiotically in much the same way private networks (protected by firewalls) interact with the Internet.



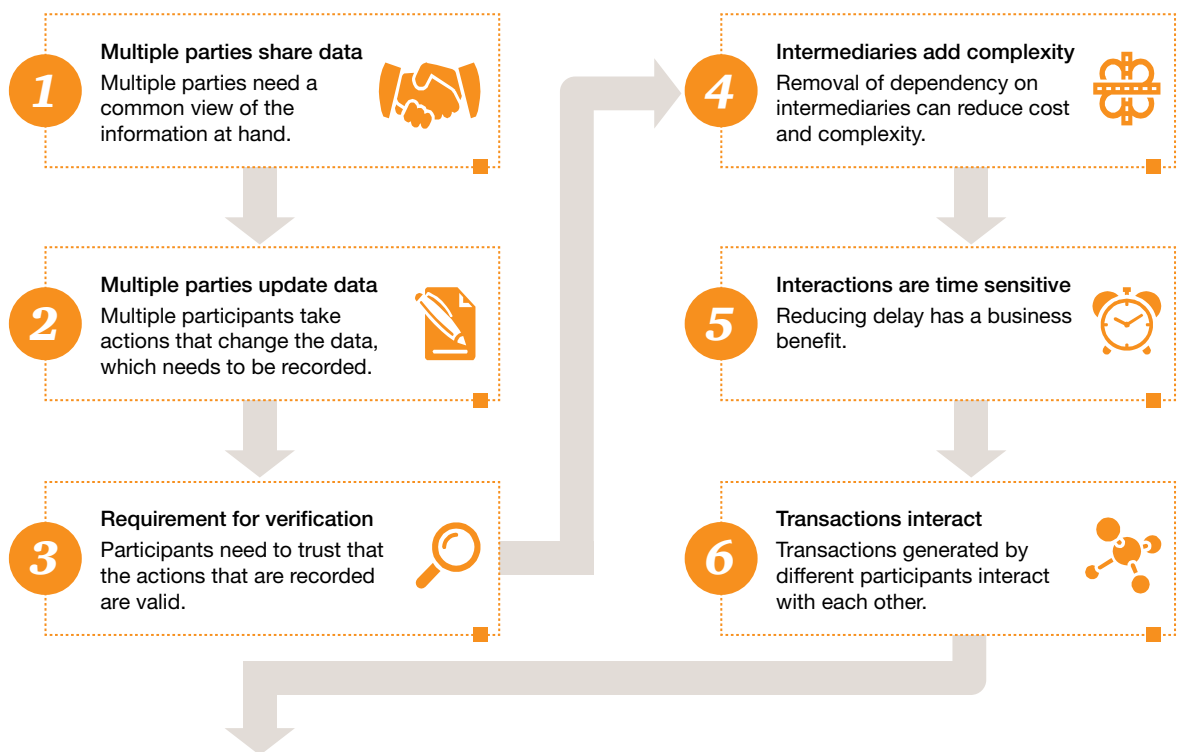


4.4. Essential prerequisites for a blockchain solution

Blockchain technology is not a one-stop solution for all problems that arise out of transacting with data and assets. It cannot be implemented in all use cases for digitisation. One must understand blockchain, its attributes and identify uses cases where this solution will be viable and useful.

There are a few essential prerequisites that can determine if blockchain technology is a viable solution. The figure below illustrates the factors that can be used to determine the effectiveness of blockchain as a solution.

Essential prerequisites for a blockchain solution



Blockchain as a solution

If the first condition is correct and three out of the remaining are considered correct then blockchain may be an effective solution to the problem.





Blockchain technology is suitable only when multiple parties share data and need a view of common information. However, multiple parties sharing data is not the only qualifying criteria for blockchain to be a viable solution. To better understand the effectiveness of a blockchain solution, we empirically define a cut-off of three out of the following five success criteria:

- 1. Multiple parties update data**
When actions undertaken by multiple parties need to be recorded and the data coming from multiple parties needs to be updated
- 2. Requirement for verification**
When it is necessary to build trust amongst parties and make them understand that their actions that are being recorded are valid
- 3. Intermediaries add complexity**
When a transaction is dependent on multiple intermediaries and their presence increases the cost and complexity of the transaction
- 4. Interactions are time sensitive**
When it is beneficial for the business to reduce delay and expedite a transaction
- 5. Transactions interact**
When transactions created by multiple participants interact and depend on each other

If at least three of these criteria are not important, then blockchain is not needed and the current solution is satisfactory. To summarise, blockchain technology is definitely not a solution to all transaction-related problems.

Transformative potential of blockchain technology

The Internet had a dramatic impact on the public sector. Governments moved from physical to digital mediums for storing important information (public records), created information and communications technology (ICT) platforms to connect people in the remotest areas and moved from manual service delivery to efficient digital delivery of services, among a host of other transformative changes that the Internet brought about.

Blockchain technology will potentially have a similar transformative impact on government service delivery and functioning as the Internet. Blockchain technology can power a new type of Internet, 'the Internet of value'.

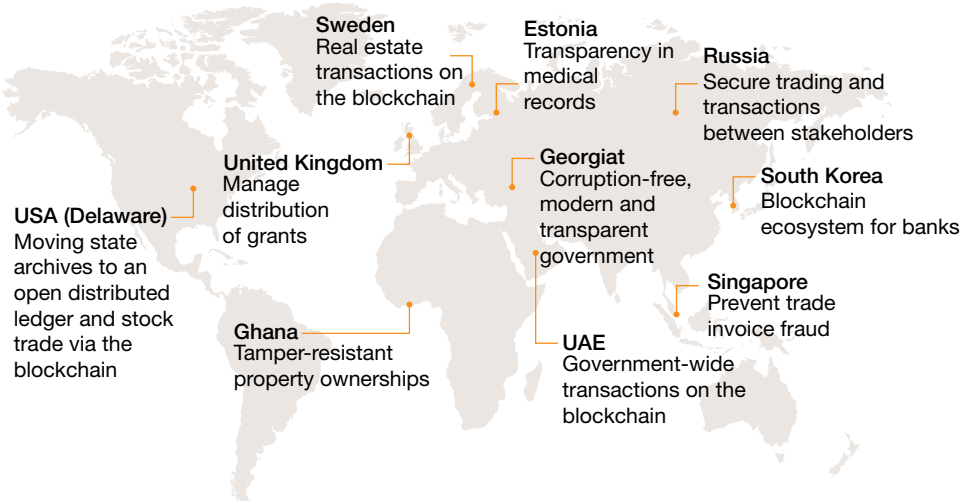
Countries such as Estonia, Georgia, the UAE, Sweden, the USA and the UK have already taken the lead in pioneering blockchain applications in the government and public sector. Dubai, which recently committed to transitioning all government transactions to blockchain by 2020 estimated that it could save nearly **100 million pages of documents generated in paperwork each year, 25.1 million hours of productive time and nearly 411 million km of travel time for its citizens.**¹⁰

Though slowly, India has also started treading down the path of blockchain adoption. Many states in India are now talking about using blockchain

technology. Andhra Pradesh, for example, announced a partnership with the Swedish firm ChromaWay¹¹ to secure citizen data on a blockchain besides also exploring blockchain use in various other fields such as smart cities and transportation. The Institute for Development and Research in Banking Technology (IDRBT), RBI, published a white paper¹² on the application of blockchain technology in the banking and financial sectors in India.

Some prominent global blockchain initiatives in the government and public sector are highlighted below.

Global blockchain initiatives



¹⁰ Staff reporter. (6 October 2016). Dubai government to embrace blockchain technology. Khaleej Times. Retrieved from <https://www.khaleejtimes.com/nation/dubai/dubai-to-embrace-blockchain> (last accessed on 4 January 2018)

¹¹ CXIHUB. (10 October 2017). Indian state partners with blockchain startup for land registry pilot. Retrieved from <https://www.cxihub.com/2017/10/10/indian-state-partners-with-blockchain-startup-for-land-registry-pilot/> (last accessed on 4 January 2018)

¹² IDRBT. (2017). Applications of blockchain technology to banking and financial sector in India. White paper. Retrieved from <http://www.idrbt.ac.in/assets/publications/Best%20Practices/BCT.pdf> (last accessed on 4 January 2018)





The following section examines four global blockchain initiatives in the government and public sector space.

Republic of Georgia¹³

Land title registration



What

The National Agency of Public Registry (NAPR) has initiated a pilot project with Bitfury for land title registration on the blockchain in April 2006. It is aimed at reducing property registration fees in Georgia and guarantees safe transactions, transparency and flexibility.



How

It is a private permissioned blockchain system that is anchored to the bitcoin blockchain network.



Outcome

1. Service delivery time was reduced from 1–3 business days to few seconds.
2. Operational costs were reduced up to 90% (for the specific service).
3. Real-time audit capabilities were enabled.

Estonia¹⁴

360 governance



What

Estonia has developed a blockchain solution to a host of government services on its own blockchain solution called keyless signature interface (KSI) to secure government repositories, integrate and maintain national e-health records, and facilitate the creation of location independent companies.



How

KSI is a blockchain technology designed in Estonia and used globally to make sure networks, systems and data are free of compromise while maintaining complete data privacy.



Outcome

Estonia's adoption of blockchain technology has created a successful test bed for generalised government applications for the blockchain such that it can be seen as a blueprint for success for potential blockchain applications elsewhere.

13 Shin, L. (7 Feb 2017). The first government to secure land titles on the bitcoin blockchain expands project. Forbes. Retrieved from <https://www.forbes.com/sites/laurashin/2017/02/07/the-first-government-to-secure-land-titles-on-the-bitcoin-blockchain-expands-project/#43bb76154dcd> (last accessed on 4 January 2018)



Delaware (USA)¹⁵

Stock ownership



What

Delaware is implementing a blockchain system to track 'precise' stock ownership through a single ledger in real time.



How

In July 2017, the state of Delaware approved stock trading via the blockchain by passing a bill that was drafted to address some of the gaps in the legal and legislative framework to regulate blockchain technology.



Outcome

It is a pioneering attempt to unwrap the regulatory challenges associated with widespread application of blockchain technology and as such it has already created a huge buzz in the industry with many companies wanting to capitalise on the new trade environment that comes with the deregulating effect of the blockchain.

Dubai (UAE)¹⁶

360 governance



What

Dubai has partnered with IBM (strategic partner) and Consensus (city advisor) to implement a solution to enable all government transactions on the blockchain as a part of the 'Smart Dubai' initiative.



How

The implementation will be carried out through a three-step approach.

1. Efficiency in government transactions by leveraging the blockchain
2. Industry creation for new business supported by the blockchain by 2020
3. International leadership in blockchain adoption



Outcome

Dubai has emerged as a pioneer in the global space of blockchain application and has drastically reduced the economic costs associated with current bureaucratic processes. With the blockchain, Dubai is expected to save:

1. 100 million pages of documents every year
2. 25.1 million hours of productivity every year
3. Citizens would save 411 million km of travel every year

¹⁵ Dinkins, D. (20 Sep 2017). Delaware approves tracking of stock ownership on blockchain, major effects. Cointelegraph. Retrieved from <https://cointelegraph.com/news/delaware-approves-tracking-of-stock-ownership-on-blockchain-major-effects> (last accessed on 4 January 2018)

¹⁶ Staff reporter. (6 October 2016). Dubai government to embrace blockchain technology. Khaleej Times. Retrieved from <https://www.khaleejtimes.com/nation/dubai/dubai-to-embrace-blockchain> (last accessed on 4 January 2018)



Although a few steps have been taken in India, the adoption of blockchain technology is still at a very nascent stage.

The following is a broad list of use cases where blockchain can have an impact:



1. Healthcare

The digitisation of health records has brought about significant change in the public health sector, but it has been criticised for being complex on account of centralisation and associated ethical issues. Blockchain technology can disrupt public health by creating a secure and flexible ecosystem for exchanging electronic health records (EHRs). This technology could also make the space more transparent by creating provenances for critical drugs, blood, organs, etc. In addition, by putting all medical licenses on a blockchain, fraudulent doctors can be prevented from practising.



2. Education

Student records, faculty records, educational certificates, etc., are key assets in the education domain. Such records need to be shared with multiple stakeholders and it is imperative to ensure that they are trustworthy. The provenance of these records also needs to be determined accurately. Student records, faculty records and educational certificates can be maintained with the application of blockchain technology. Blockchain can also simplify certificate attestation and verification. It could even transform the manner in which the policy for educational inclusion is framed by bringing in base uniformity in the tracking of national metrics.



3. Public safety and justice

Blockchain could make the delivery of public safety more efficient by resolving the problem of inter-agency coordination by providing a unified source of truth that each agency independently interfaces with based on predefined conditions. Establishing a chain of custody for crucial evidence is often an important prerequisite for the evidence to be admissible; blockchain technology could help establish the provenance of the chain of custody for such evidence.



4. Agriculture

Blockchain technology can be used to increase transparency, reduce complexity and cost in food-based value chains by enabling trustworthy provenance and traceability from farmer to consumer. Other possible applications include the use of blockchain technology to record and manage agricultural land records as well as agriculture insurance.



5. Civil registration

The civil registration process can be simplified through the application of blockchain technology to create distributed citizen registration platforms and even register vital events such as births and deaths on a blockchain. This can help make citizen records tamper-proof, resilient, secure and private, thus providing wide-ranging benefits for a variety of stakeholders.



6. Defence

Information regarding defence infrastructure and computer systems is critical to national security. For this reason, it is distributed across different locations to prevent unauthorised access and modification. Blockchain technology can be leveraged to provide consensus-based access for modifying data and distributing access over multiple system resources such as networks, data centres and hardware equipment.



7. Governance

Government departments have functional interdependence but operate in silos, which impacts the availability of services and deteriorates citizen experience. Blockchain technology can be used to break the silos, check government corruption (if any), increase efficiency and transparency. Linking file and data movement between departments through a blockchain would increase visibility into the process and ensure that the data/file moves forward in real time.



8. Energy

Blockchain technology can be deployed to create a marketplace for electric power supply. Microgeneration of electricity through home power generation using solar energy supplements traditional power supply and promotes the use of renewable energy sources. Using smart meters, a record of produced and consumed electricity for each user in the grid can be maintained on a blockchain with credits/currency allocated to the user for surplus power supply and credits redeemed for power consumption. This essentially creates a transparent, hassle-free and efficient energy market.



For every use case that has been identified for blockchain technology, it is important to ascertain the following aspects so that a PoC can be established and the value of technology be proved.

Checklist for PoCs

✓	What is the participating business network?
✓	What is the potential integration with external systems?
✓	Who are the actors and what is their stake in each step of the solution?
✓	What are the business rules associated with each step of the solution?
✓	Who are the network participants that would validate the fulfilment of the business rule for each step?
✓	What are the roles of each network participant on the blockchain? (as an example, who would participate in consensus and who just hold a copy of the ledger)
✓	What is the actual asset class in play through each step? (An example of an asset class would be a birth registration form that is automated as a smart contract.)
✓	What is the data being added/appended to the distributed ledger with each step?
✓	What is the extent and type of addition/appendage permissible for each actor through each step?

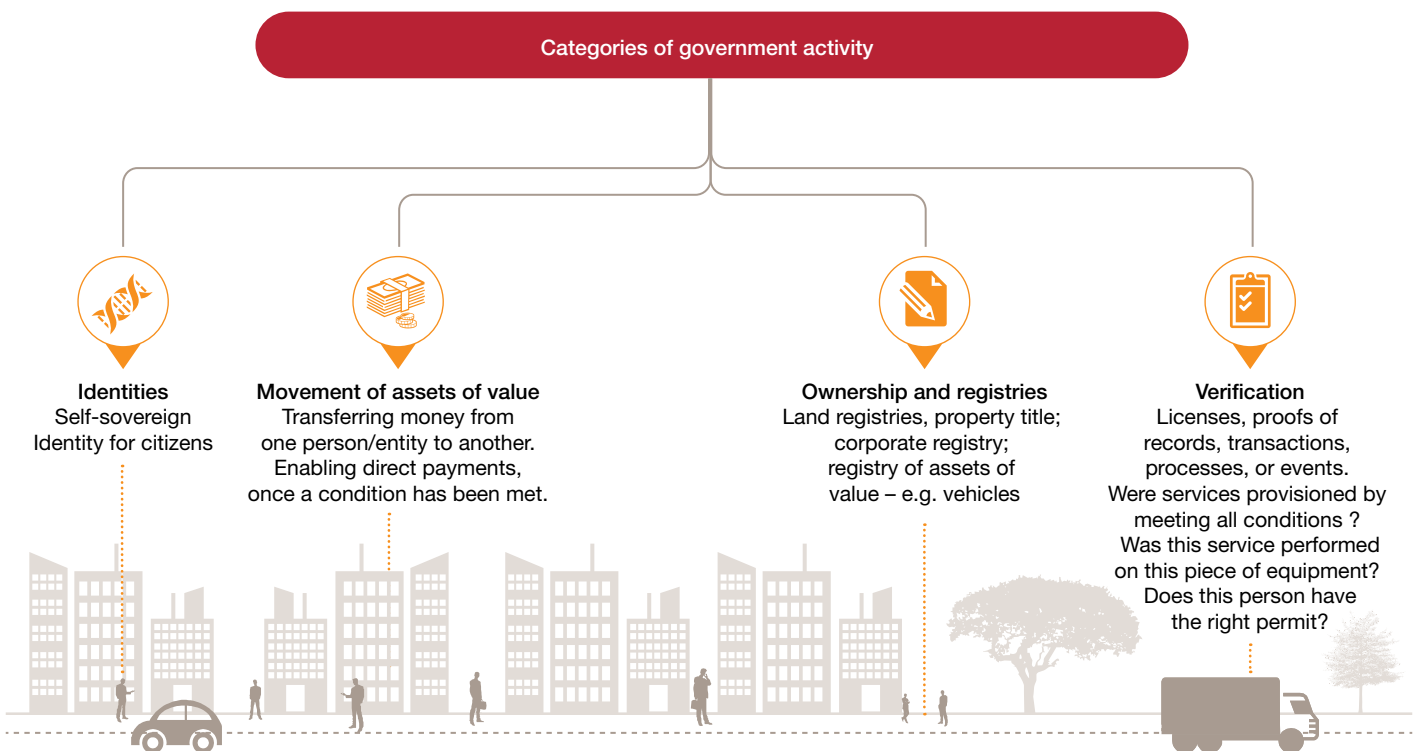


5.1. Enhancing smart city initiatives using the blockchain

The smart city concept can be looked upon as a framework for implementing a vision of advanced and modern urbanisation. Smart cities leverage technology and utilise existing and planned infrastructure investments to provide a higher quality of living to residents, a conducive investment climate for businesses and allow maximisation of resource utilisation and transparency for governments. They can be considered as an organic integration of systems, IT infrastructure, physical infrastructure, and social and business infrastructure. These systems work collectively so as to generate intelligent and actionable information for decision makers.¹⁷

Broadly speaking, the impact of blockchain in the realm of smart cities can be classified as under:

Impact of blockchain technology on smart cities



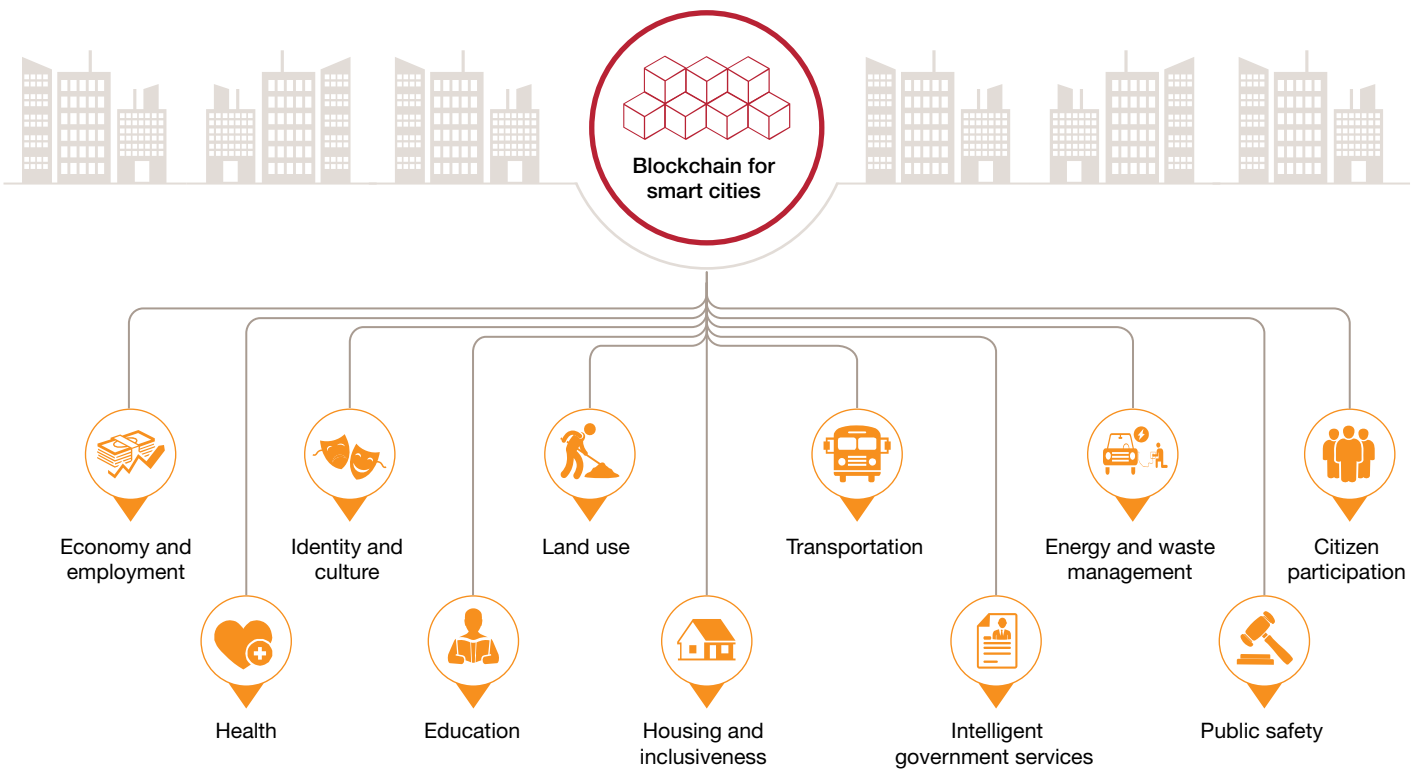
¹⁷ PwC and FICCI. (2015). India: Surging to a smarter future. Retrieved from <https://www.pwc.in/assets/pdfs/publications/2015/india-surging-to-a-smarter-future.pdf> (last accessed on 4 January 2018)

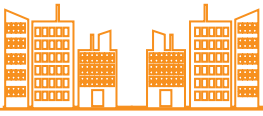


In India, the Smart Cities Mission was launched on 25 of June 2015 with the aim of creating 100 smart cities. The objective, as defined by the MoHUA, is 'to promote sustainable and inclusive cities that provide core infrastructure and give a decent quality of life to its citizens, a clean and sustainable environment and application of "Smart" Solutions'.

Blockchain presents an opportunity to make the technology initiatives of a smart city more secure, transparent, efficient and resilient in consonance with the objectives for the Smart Cities Mission, as outlined by the MoHUA.

Smart city areas where the blockchain can have an impact





The following are potential use cases of the blockchain in the smart city landscape:

Smart city area	MoHUA smart city feature
Citizen participation	Citizen participation
Definition Guideline 3.1.6	A smart city constantly adapts its strategies by incorporating the views of its citizens to bring maximum benefit for all.
Blockchain use case	Description
Citizen loyalty and reward platform	A blockchain-based loyalty and rewards platform can ensure that the right set of contributors from civil society are recognised and rewarded for their contribution in smart city planning and development. Such an initiative can make the smart city vision more inclusive and broad-based and foster multi-way communication across stakeholders.
Decentralised voting platforms for local elections and legislative issues	Blockchain-based voting platforms can achieve secure, anonymous and unique voting in a decentralised (digitised) manner by removing inefficiencies and complexities that characterise other forms of voting. Such platforms can be used to poll citizens on furthering pan-city initiatives.
Public grievance management and addressal system with a blockchain-based feedback system	Blockchain maintains immutability and, as such, this principle can be applied to creating trustworthy feedback and grievance addressal systems that allow citizens to 'rate' and provide feedback/raise a grievance on issues that matter to them.
Smart city area	MoHUA smart city feature
Economy and employment	Economy and Employment
Definition Guidelines 2.6, 3.1.7 and 6.2	A smart city has a robust and resilient economic base and growth strategy that creates large-scale employment and increases opportunities for the majority of its citizens.
Blockchain use case	Description
Local business registry	A local business registration system on a blockchain can effectively manage the life cycle of a corporate from inception to dissolution and provide a 360-degree view to all interested parties in a trustworthy manner, increasing ease and decreasing the cost of doing business. Such a business registry can help local business set-up and resolve issues faster. Integration with the centralised Corporate Registry(s) may be needed to realise the full potential in the long run.
Trade finance and logistics	Blockchain-based logistics (and finance) management solutions can help create sustainable value chains that drive efficiency, bring down costs and create transparency by removing needless layers of verification. Implementation of trade finance and logistics on a blockchain at the state/central level could be leveraged at the city level to realise benefits.
Certification process for 'recognition of prior learning' and 'Skill development' for both white and blue-collar jobs	A blockchain-based employment register for workers can drive transparency and trust in certifying past employment and relevance thereof by providing a 360-degree view of employment history. Such a process can lead to more certainty and trust among citizens with regard to obtaining common services like plumbing and carpentry.

Smart city area	MoHUA smart city feature
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Health	Health
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Definition Guideline 2.5.10	A smart city provides access to healthcare for all its citizens.
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Blockchain use case	Description
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Electronic health records	The key attributes of provenance and immutability can be used to provide a single electronic health record(EHR) for citizens by providing a secure, flexible and trustworthy ecosystem for patients and health providers. Such EHRs can significantly reduce the challenges around citizens having to carry multiple health records across care providers who often don't recognise their validity.
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Provenance of controlled and critical drugs	Usage of controlled drugs can be better monitored and controlled, resulting in right availability and lower drug abuse. This is particularly relevant in cases where cities want to prevent the abuse of controlled drugs.
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Registration of care providers	Registration of care providers (practitioners and facilities) and its renewal on a blockchain has the potential to increase trust in the system and ensure better control around who can practice medicine and who can provide allied medical services in the city (e.g. pharmacies, radiology centres).
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Visibility of pharma supply chain	A blockchain can also be utilised to create transparent pharmaceutical supply chains, especially for critical drugs and organs. Such a system, if it exists centrally, can be leveraged at a city level—or a city could take this up as a first pilot.
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Processing of insurance claims	Blockchain-based smart contracts can be used to manage insurance claims to provide an irrefutable and responsive automation mechanism for claims approval and settlement. Such a system, if it exists centrally, can be leveraged at a city level—or a city could take this up as a first pilot.
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Smart city area	MoHUA smart city feature
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Identity and culture	Identity and culture
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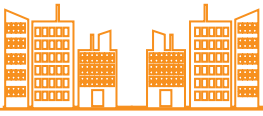
Definition Guideline 3.1.7	A smart city has a unique identity, which distinguishes it from all other cities based on some key aspect: its location or climate, its leading industry, its cultural heritage, its local culture or cuisine, or other factors. This identity allows an easy answer to the question 'Why in this city and not somewhere else?' A smart city celebrates and promotes its unique identity and culture.
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Blockchain use case	Description
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Registry of monuments	A single registry of monuments/places of interest can help in better preservation by ensuring that only authorised agencies are allowed to provide services, thus maintaining the sanctity of the heritage.
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Ticketing for visiting places of interest and for heritage events	A blockchain can ensure that the tickets for entry to monuments and for events are delivered based on a person's identity and cannot be transacted in the black market. Such an approach will ensure that citizens can trust the tickets they receive and the secondary sales market gets regulated.
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Aids and grants management for civil society groups involved in managing identity and culture	Blockchain-based grants management will ensure that grants for maintaining culture and identity go to the right entities and are spent for the right purposes. Such a system will ensure that culture and heritage are preserved and government grants are used for the right purpose.
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Smart city area	MoHUA smart city feature
Education	Education
Definition Guideline 2.5.10	A smart city offers schooling and educational opportunities for all children in the city.
Blockchain use case	Description
360-degree and longitudinal view of student	Blockchain-based education records management ensures that the government can get a holistic view of a child's credentials. Also, the educational records can be secured and shared with stakeholders through automated consent mechanisms, thereby making attestations redundant. Integrated with the population registry, such a system can help ensure literacy targets are met and drop-outs minimised with proper interventions
Benefits management for children from various underprivileged sections	A blockchain-based grants management system for relevant children will ensure that the right grant reaches the right child at the right time, and that (de)enrolment and mapping of change of circumstances are done transparently and seamlessly.
Smart city area	MoHUA smart city feature
Land use	Mixed use
Definition Guideline 3.1.2	A smart city has different kinds of land uses in the same places—for instance, clusters of offices, houses and shops.
Blockchain use case	Description
Land and property registration and life cycle management	Property registration on a blockchain can eliminate problems associated with tenuous land titles while creating a digitised process to automate property registration, thus eliminating cost and time taken. Such a system will increase the trust in the system, thereby improving the economy. Specifically for new developments in a smart city, such a blockchain-based system can be piloted and then slowly integrated in the rest of the city.
Approvals for building design/construction and inspection/self-certification	As a subset of land/property registry, all approvals, inspection reports and self-certification can be recorded against the land/property, thus providing an immutable 360-degree view of the said asset.
Smart city area	MoHUA smart city feature
Housing and inclusiveness	Housing and inclusiveness
Definition Guideline 3.1.2	A smart city has sufficient housing for all income groups and promotes integration among social groups.
Blockchain use case	Description
Housing allocation process/lottery system	A blockchain-based auction/lottery system based on the identity of the respective citizens (validated through smart contracts) will ensure that houses are only allocated to the right citizens/user groups. Such a system will help improve the trust in the allocation process as a blockchain can make such a system transparent and openly auditable. Also, all transactions get captured immutably, resulting in increased accuracy in record keeping.

Smart city area	MoHUA smart city feature
Transportation	Transportation and mobility
Definition Guidelines 3.1.5 and 6.2	Residents of a smart city do not require an automobile to get around. Distances are short, buildings are accessible from the sidewalk, and transit options are plentiful and attractive to people of all income levels.

Blockchain use case	Description
Blockchain-enabled P2P vehicle sharing	P2P vehicle sharing on a blockchain network can help address first and last mile connectivity in a city and reduce private vehicles, thus promoting decentralised public transportation. A blockchain-based system can provide the reputation management capability which is essential for P2P vehicle sharing.
Blockchain-based vehicle registry	Vehicle registry on a blockchain can provide life cycle provenance for a vehicle, thus ensuring only the right vehicles ply on the smart city roads. Such a registry combined with the right IoT systems (e.g. automated number plate recognition cameras) can ensure that warnings are provided to owners of outdated vehicles.

Smart city area	MoHUA smart city feature
Intelligent government services	Intelligent government services
Definition Guidelines 2.4.7, 3.1.6, 5.1.4 and 6.2	A smart city enables easy interaction (including through online and telephone services) with its citizens, eliminating delays and frustrations in interactions with the government.

Blockchain use case	Description
Citizen identity	Citizen identity on a blockchain can deliver the promise of self-sovereign identity to citizens across all identity (biometric) and attributes (health, education, tax, etc.). Such a use case has immense potential to eliminate paperwork and further the Digital India push.
Civil registration	Moving all civil registration (birth and death registration) to a blockchain will improve trust in issuance and reduce fraud on usage of these credentials. Issuance of these credentials on a blockchain can be tied to the identity of an individual and can then be provided to other entities based on consent, thus eliminating attestation processes and paperwork.

Smart city area	MoHUA smart city feature
Energy	Energy supply
Definition	A smart city has reliable, 24/7 electricity supply with no delays or outages.

Blockchain use case	Description
Blockchain-based smart meters	They can help accelerate the enforcement of real-time differential pricing models to contain energy usage. Such models can promote local self-dependency on energy. Blockchain-based renewable energy microgrids connected to the main grid can help local communities manage the power supply and load they need. A blockchain-based energy billing system can efficiently enforce real-time differential pricing for consumption.



Smart city area	MoHUA smart city feature
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Energy	Energy source
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Definition Guideline 6.2	A smart city has at least 10% of its electricity generated by renewables.
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Blockchain use case	Description
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Renewable energy on blockchain	Consumers become prosumers by investing in micro-renewable energy farms (solar, wind) and can choose the amount of energy required for day-to-day use and sell the excess back to the grid. A blockchain-based renewable energy billing system will incentivise citizens to move to renewable sources due to the trust in the system.
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Renewable energy/emission allowances, guarantees, tracking and monetisation	Such a billing system will be able to incentivise citizens for the energy they pump back into the grid and for the renewable energy they use.
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Smart city area	MoHUA smart city feature
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Energy	Energy efficiency
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Definition Guideline 6.2	A smart city promotes state-of-the-art energy efficiency practices in buildings, street lights and transit systems.
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Blockchain use case	Description
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Electric vehicle charging	With the advent of electric vehicles, a blockchain-based system will ensure that the bill for the charging will always be raised on the vehicle owner irrespective of the point of charge, thus removing barriers to widespread adoption.
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Smart city area	MoHUA smart city feature
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Water and waste water	Water supply
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Definition Guidelines 2.4 and 6.2	A smart city has a reliable, 24/7 supply of water that meets national and global health standards.
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Blockchain use case	Description
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Blockchain-based water distribution grids	Smart tracking meters can be used to track water supply, while business rule validation on blockchain-based smart contracts can be used to automate water supply management over the grid by creating business rules that ensure that distribution of water takes place in the most efficient manner possible.
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Smart city area	MoHUA smart city feature
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Air quality	Air quality
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Definition Guideline 2.4.8	A smart city has air quality that always meets international safety standards.
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Blockchain use case	Description
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Reputation management system of companies based on emissions	<p>A blockchain-based reputation management system for companies (that tracks emissions and records them on a blockchain network periodically) can help create an immutable source of truth that is verifiable and transparent.</p> <p>This transparency could drive more environmentally diligent practices from constituent companies.</p>
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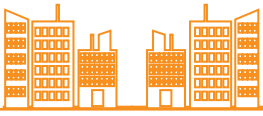
Smart city area	MoHUA smart city feature
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Waste and sanitation	Waste management
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Definition Guidelines 2.4.3 and 6.2	A smart city has a waste management system that removes household and commercial garbage, and disposes of it in an environmentally and economically sound manner.
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Blockchain use case	Description
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Waste management on blockchain and IoT	<p>Blockchain technology can be combined with IoT solutions that accurately track the levels of waste production/disbursal at critical points in order to provide more efficient and better aligned waste management strategies.</p> <p>Efficient waste management systems with relevant rewards and penalties can be enforced through a combination of blockchain and IoT-based solutions. For example, waste management companies can be incentivised for ensuring that the bins in a locality are always cleared on time based on their 'level'.</p>
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Smart city area	MoHUA smart city feature
Safety	Safety
Definition Guideline 6.2	A smart city has high levels of public safety, especially focused on women, children and the elderly; men and women of all ages feel safe on the streets at all hours.
Blockchain use case	Description
Evidence chain of custody under evidence act on blockchain	A blockchain-based system ¹⁸ can unambiguously and cryptographically verify that the evidence produced in court is exactly identical to the one obtained at the time of the event, and has not been altered or processed in any way. This will result in fewer disputes on evidence and faster processing of cases in the courts, thus reducing the burden on law enforcement agencies.
Evidence book and case management on blockchain	All associated evidence on a particular case can be registered immutably against the case on a blockchain, resulting in a 360-degree view of the case and minimising evidence tampering.
Information security and safety	By leveraging a distributed ledger and eliminating the risk of a single point of failure, blockchain technology provides end-to-end privacy and encryption while still ensuring user convenience. ¹⁹

While the above use cases provide an insight into the potential blockchain technology has to make cities smart, we recognise that some of these use cases may not be directly executable under the purview of the city administration or the smart city special-purpose vehicle (SPV) and will need the consent of/collaboration with state and central governments. As outlined later, it is important to choose the right use case, test it out and then expand the horizon.

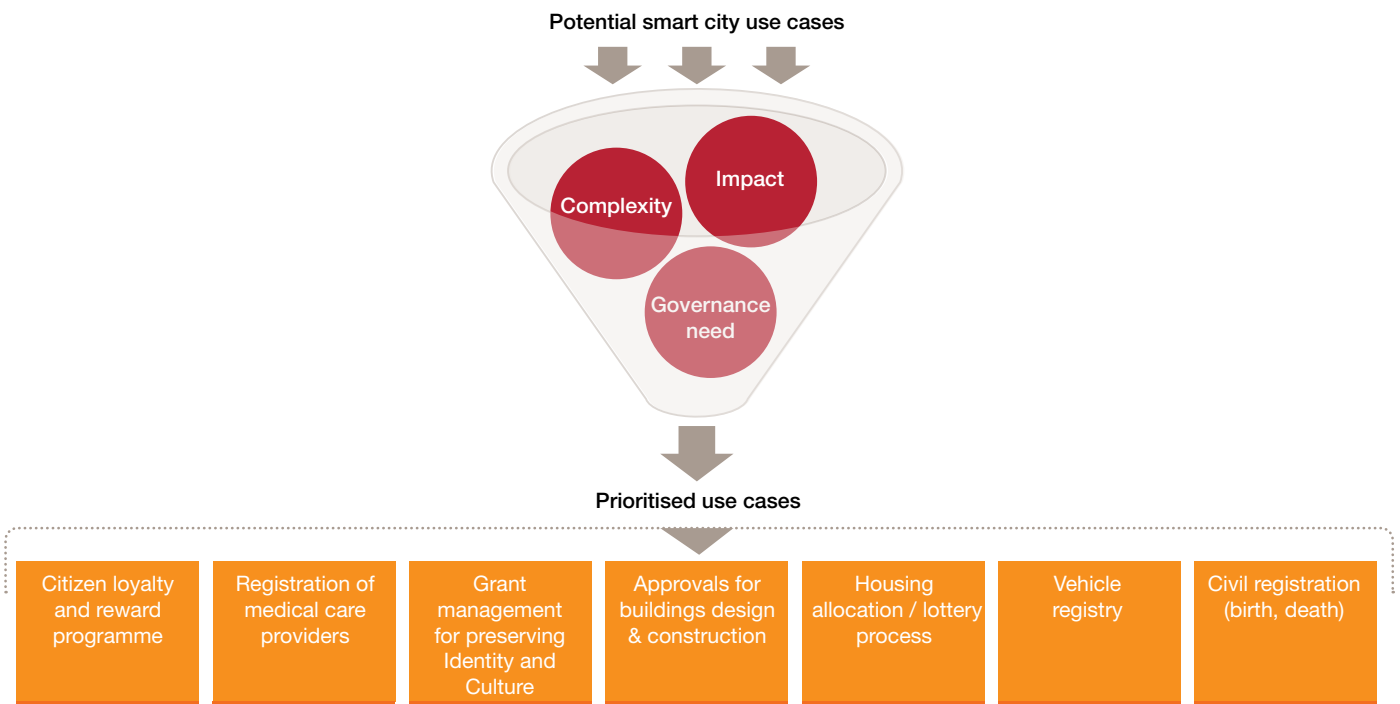


18 Davidson, J. (2 Nov 2017). Increasing trust in criminal evidence with blockchains. MOJ Digital & Technology, Government of UK. Retrieved from <https://mojdigital.blog.gov.uk/2017/11/02/increasing-trust-in-criminal-evidence-with-blockchains/> (last accessed on 4 January 2018)

19 Barzilay, O. (21 Aug 2017). 3 ways blockchain is revolutionizing cybersecurity. Forbes. Retrieved from <https://www.forbes.com/sites/omribarzilay/2017/08/21/3-ways-blockchain-is-revolutionizing-cybersecurity/#4f5761842334> (last accessed on 4 January 2018)

Our initial view on the prioritisation of these use cases for implementation under the smart city programme is outlined below.

High-priority blockchain initiatives



Each of the smart city use cases were run through a filter of three attributes and then prioritised:

- 1. Impact**
A comparison of the impact of such a solution with that of traditional solutions
- 2. Complexity**
Measured in terms of time taken, parties involved and technology complexity
- 3. Governance need**
Measured in terms of ability to execute with high autonomy within the SPV

It is recommended that an analysis be carried out at each city level across these use cases and the priority ones be identified for pursuing adoption through a structured approach outlined later in this paper.

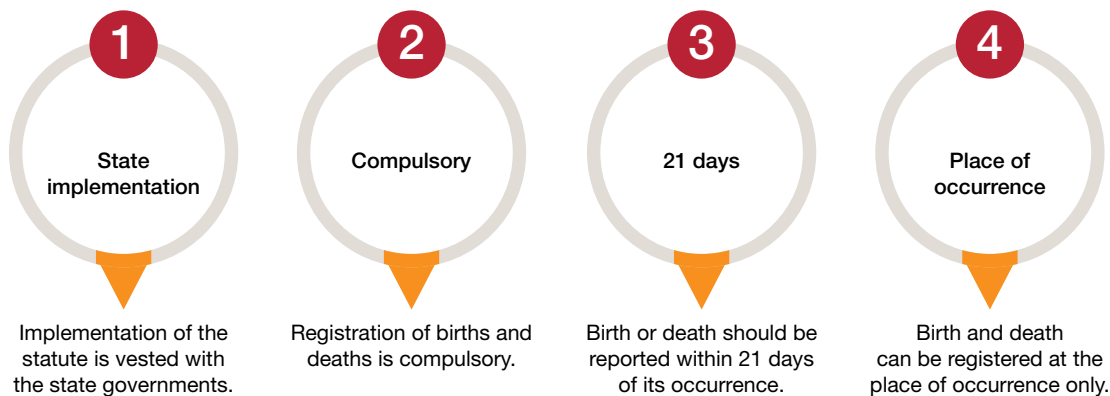
Detailed use cases

A few use cases for blockchain in smart cities have been detailed in this section in order to highlight the advantages of blockchain and provide potential functional flows of blockchain-based solutions.

6.1. Birth and death registration

The Civil Registration System in India comes under the purview of the Registration of Birth and Deaths Act, 1969. The salient features of birth and death registration in India are:

Features of birth and death registration in India



The number of civil registrations in India has grown over the last two decades. Birth registration has gone up from 58% to 88.8% in between 2001 and 2014; similarly, incidents of registered deaths have gone up from 54% to 74.3% in the same period.²⁰ While these are positive indicators, many systemic problems still exist with regard to accuracy, uniformity, completeness and timeliness. Some of the key indicators associated with these problems are given below:

1. Incomplete coverage

Low utility of registration certificates, use of supplementary documents instead of birth certificates and a general sense of apathy and lack of awareness among citizens inhibit the spread of birth and death registration, thus resulting in their incomplete coverage. As of 2014, the rate of death registration in some of the lowest performing states such as Bihar (24.1%), Arunachal Pradesh (28.7%) and Nagaland (27.3%) hovered between 20–30%.²¹

²⁰ Office of the Registrar General & Census Commissioner, India (n.d.). Civil Registration System Division. Ministry of Home Affairs, Government of India. Retrieved from http://www.censusindia.gov.in/vital_statistics/CRS/CRS_Division.html (last accessed on 4 Jan 2018)

²¹ Office of the Registrar General & Census Commissioner, India. (n.d.). Civil Registration System Division. Ministry of Home Affairs, Government of India. Retrieved from http://www.censusindia.gov.in/vital_statistics/CRS/CRS_Division.html (last accessed on 4 January 2018)

Programme Evaluation Organisation, Planning Commission, Government of India. (February 2011). Evaluation study on National Rural Health Mission (NRHM) in seven states. Retrieved from http://planningcommission.gov.in/reports/peoreport/peo/NRHM_v1.pdf (last accessed on 4 January 2018)





2. Interdepartmental silos

While a few states have moved to digital platforms for registration, many others still maintain manual records. The methods of registration, data collection and verification vary greatly.

3. Accuracy of registered information

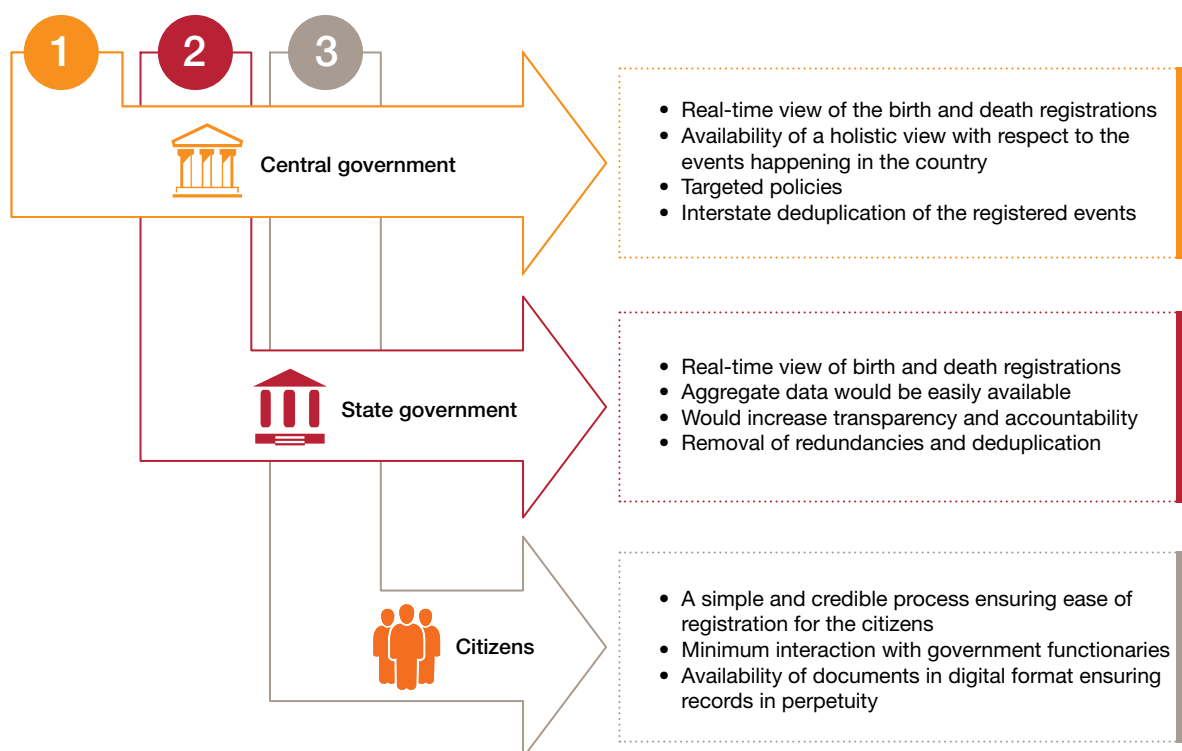
Problems related to authenticity of birth certificates lead to a variety of issues such as problems with resource allocation through public distribution initiatives and misrepresentation of vital information for transactional purposes.

4. Discrepancies in macro-level indicators

A combination of inaccurate and incomplete information creates discrepancies in deduced macro-level indicators such as infant mortality rates and demographic ratios. These indicators usually form the data point for relevant policy development and decision making. Their misrepresentation impacts the allocation of resources for future initiatives, policy development and decision making.

A few of the issues in birth and death registration can be resolved by blockchain-based digitisation. Blockchain provides the advantage of immutability, leading to true provenance and finality, thereby making it a platform of choice for the digitisation of birth and death records. The figure below illustrates the key advantages of using blockchain-based solutions to address the problems associated with birth and death registration.

Advantages of blockchain technology in birth and death registration

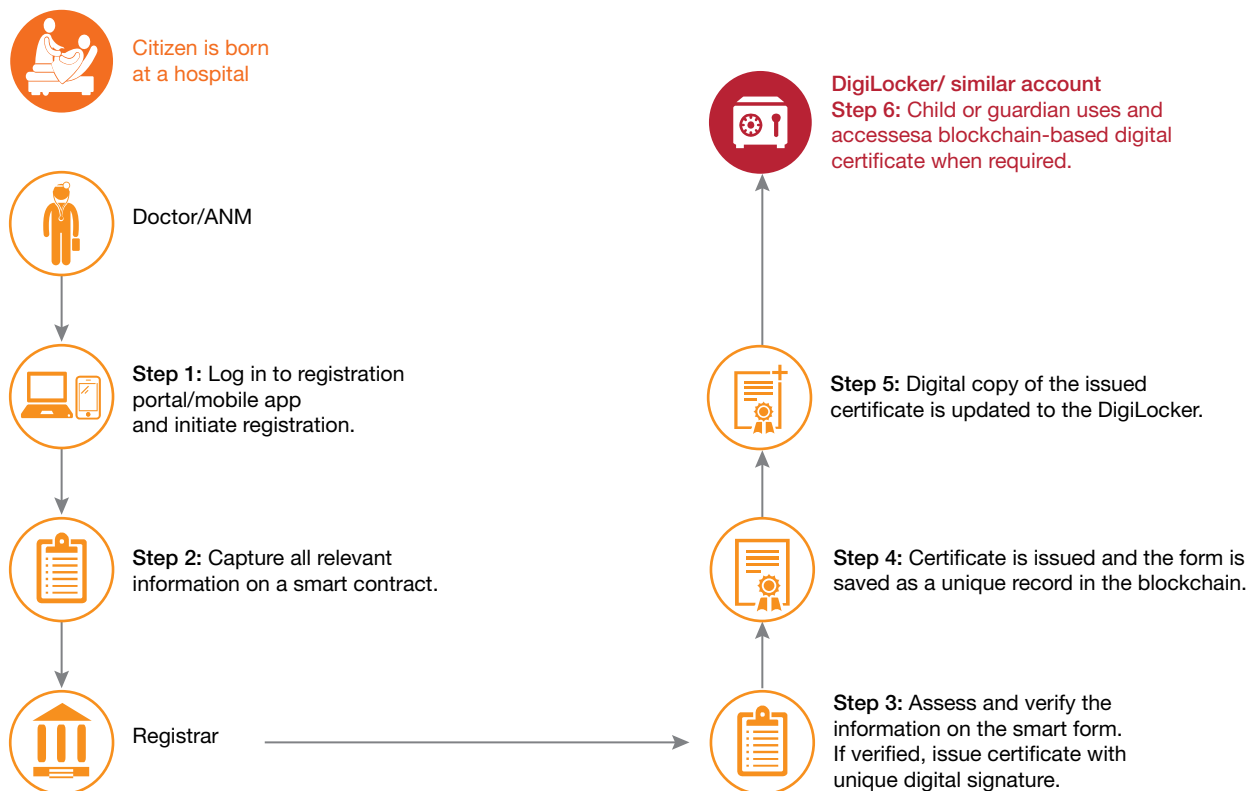




Use case: Birth registration through blockchain

The figure below depicts describes a potential process flow for birth registration through a blockchain.

Birth and death registration on a blockchain



The following are the key steps for registration of birth via blockchain as per the process flow described above:

- Upon the birth of a child, the doctor/ANM in charge will log into a user interface that will act as the registration portal linked to a smart contract in the blockchain network. The doctor will use a unique property reference number (UPRN), while the ANM will use an ANM ID for logging in.
- All relevant information (date of birth, name, domicile, blood group, guardian information, etc.) shall be updated to editable fields in the smart contract. For the purpose of filling information pertaining to the guardian/parent, Aadhaar shall be used.
- The smart contract moves to parents' node, where the parents of the newborn review the information and digitally sign the form.
- The smart contract moves to the registrar's node, where the registrar validates each field in the 'smart form' with a binary response (valid or invalid).
- If all fields in the smart form are valid, a unique digital signature associated with that form is generated, which is stamped to the record and updated to the blockchain. A corresponding record will be generated as a certificate that will now be updated to the citizen's DigiLocker/similar account, imprinted with a unique digital signature.

6.2. Social benefits

Governments all over the world spend significant portions of their budgets on social benefit schemes to take care of their poor, sick, the elderly, underprivileged and marginalised. However, an important aspect of such schemes is to prevent welfare spending from ballooning extravagantly and ensuring that recipients spend the money wisely. Financial inclusion of citizens is one of the key enablers for the disbursement of subsidies directly to beneficiary bank accounts, thereby reducing leakages.

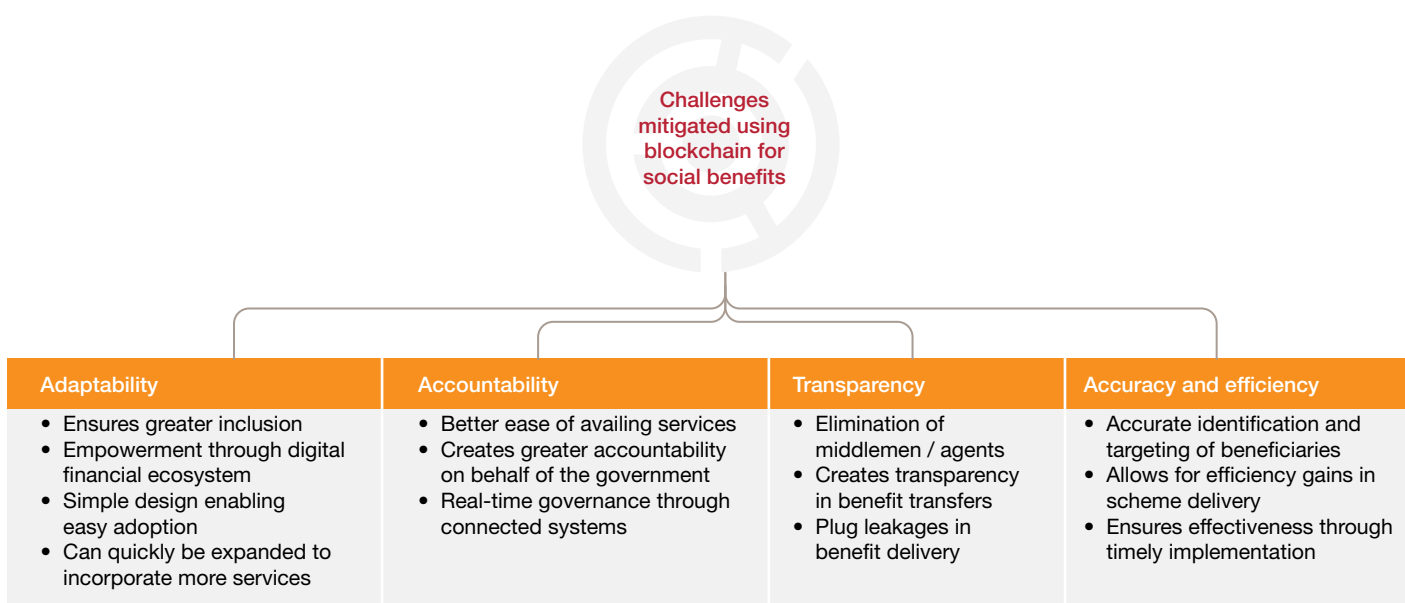
An estimated 2.5 billion adults worldwide are excluded from the formal financial system. In India, over 600 million people lack access to banking services and close to 300 million people live below the official poverty line. These people largely rely on government welfare payment schemes such as the National Rural Employment Guarantee Act, 2005, old age pensions, scholarships, widow pensions, discounted LPG cooking gas and other subsidies for their sustenance.

The Government of India makes these payments through the Direct Benefit Transfer (DBT) scheme which covers beneficiaries under 407 different schemes with a cumulative payout of 2.68 lakh crore INR (cumulative till December 2017).²² DBT aims to eliminate corruption, inefficiencies and leakages to provide inclusive growth, deliver better welfare measures and eradicate poverty. Under DBT, each beneficiary establishes his/her identity and produces multiple documents to verify his/her eligibility before several authorities.

However, a few challenges still exist, including financial losses through fraud and error, a large number of unbanked welfare claimants, cost of unauthorised transactions, high transaction costs and prioritising the most vulnerable citizens.²³

By removing the need for third parties to manage transactions and keep records, blockchain technology can massively reduce transaction costs and help mitigate these challenges. Leveraging blockchain technology for social benefit schemes will support the government's wider policy objectives of sustainability, thus reducing poverty and generating value for money in public expenditure.

Challenges mitigated using the blockchain for social benefits



²² Direct Benefit Transfer, Government of India. Retrieved from <https://dbtbharat.gov.in/> (last accessed on 4 Jan 2018)

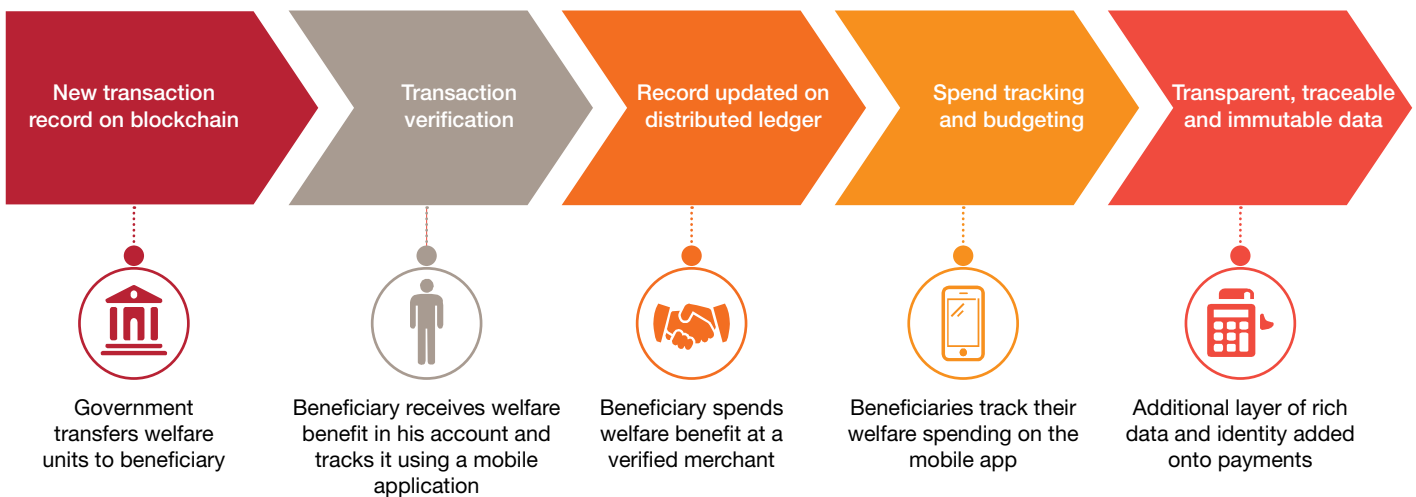
²³ Asian Development Blog. (26 September 2017). Direct benefit transfer – a game-changer for financial inclusion in India. Retrieved from <https://blogs.adb.org/blog/direct-benefit-transfer-game-changer-financial-inclusion-india> (last accessed on 4 Jan 2018)



Use case: Blockchain-based social benefits payments²⁴

Blockchain technology can be used to create a secure and highly efficient welfare infrastructure that can prevent fraud and pilferage of social benefits. One of the potential use cases for blockchain-based social benefits payments is shown below. Beneficiaries will receive welfare benefits using a system that comprises a mobile app and blockchain system to record payments sent or received by welfare recipients.

Social benefits on blockchain



The following is the series of events that take place when a transaction is made using a blockchain:²⁵

- Beneficiaries are enrolled based on the relevant enrolment criteria. The enrolment criteria can potentially be managed using a smart contract where enrolment/de-enrolments are taken care of automatically using the smart contract.
- Beneficiaries use a mobile app on their phones/tablets through which they receive their benefits payments. The system uses a private permissioned distributed ledger to allow users to store their transactions.
- Beneficiaries spend their welfare tokens/credits/currency at pre-verified merchants.
- Beneficiaries then view their transactions securely on the mobile application, which allows them to monitor and allocate their spending into categories, see their available benefits and budget their spending accordingly.
- Their transactions are recorded on a distributed ledger to support their financial management. This strand of secure, tamper-resistant data on the distributed ledger would help in more effective information exchange.
- Smart contracts automatically check for change of circumstances (that can lead to a change in benefits or de-enrolment) and update the ledger periodically.

Additionally, the system creates an incremental layer of richer data and identity onto payments so that a deeper and more effective relationship can be established between the government and beneficiaries.

²⁴ Benjamin Cheah Kai Wai. (24 May 2017). Can blockchains revolutionise social welfare programmes? Retrieved from <https://www.benjamincheah.com/2017/05/24/can-blockchains-revolutionise-social-welfare-programmes/> (last accessed on 4 Jan 2018)

²⁵ UK Government pilot uses blockchain tech for welfare distribution <https://bravenewcoin.com/news/uk-government-pilot-uses-blockchain-tech-for-welfare-ribution/>

6.3. Land registration management

Land registration management refers to the registration/management of all land deeds/transactions undertaken in any geographical jurisdiction of a governing authority. In most countries, these records are maintained with various government and local bodies. However, the registration of land records does not confer 'land title', which at times leads to title disputes and costly litigation.

Landowners around the globe are susceptible to manipulation by individuals or groups with vested interests who can undermine the validity of their ownership. It is estimated that over 70% of the people in the world who own land have a tenuous title against it.²⁶ In principle, a valid land title is a very important symbol of economic mobility. This holds true because one can't borrow against land that is not legally one's own. The situation gets more complicated on considering the impact on the vast majority of people that depend on primary economic activities such as agriculture for their sustenance, especially in agrarian economies like India. There are countless examples all over the world where land has been usurped by falsifying records.

The key issues with land registration in India are:

1. Tenuous land titles

It is estimated that approximately 1.3% of the GDP is lost due to unclear land titles.²⁷ The litigation cost associated with competing claims only serves to exacerbate the problem further.

2. Information silos

There is very little uniformity in the way centralised databases of all land records are maintained. As such, most of these records are maintained in silos with very little interoperable information accessible to stakeholders on other platforms. This complicates the problems associated with updating and verifying records.

3. Inefficiencies in record keeping

Due to the absence of a platform to maintain uniform records, there is a lot of autonomy amongst various stakeholders. Further, these stakeholders do not coordinate with one another in order to verify the authenticity of their records. In many cases, they may be dealing with inaccurate data along with other inefficiencies associated with such record keeping.

Thus, it can be inferred that one of the key issues in land registration is the lack of authenticity of land records in the public domain. Blockchain technology can be leveraged to establish trust, transparency and accuracy in maintaining land records and building a robust land record management system. Putting land records on a blockchain would make them immutable and tamper-proof, thus securitising them and building a firm pillar of trust in the system. The resulting land record management system would be a public ledger spread over a distributed network that records each and every transaction associated with a land parcel/property in an autonomous and efficient manner.

All land deeds and their associated records would be immutable and irrefutable, thus saving a lot of money on land-related litigation. The cost of storing these records physically and the voluminous paperwork associated with verifying details about any property would reduce. This would, in turn, save time and promote transparency in the land record management system.

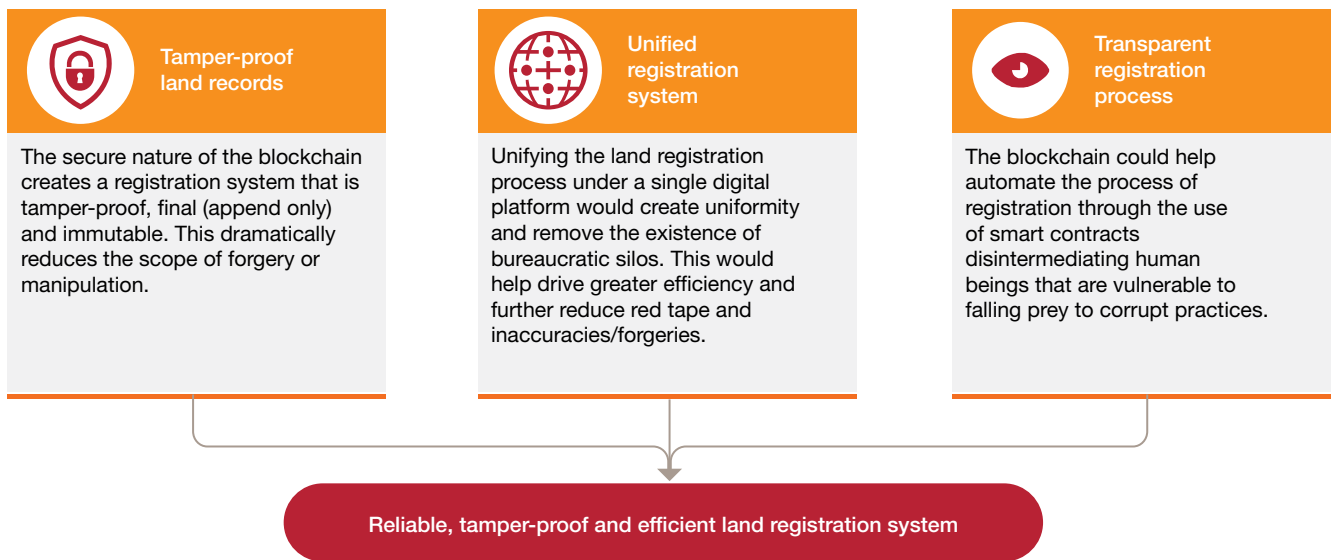
26 Tapscott, D. (June 2016). Don Tapscott: How the blockchain is changing money and business [Video file]. Retrieved from https://www.ted.com/talks/don_tapscott_how_the_blockchain_is_changing_money_and_business/transcript (last accessed on 4 Jan 2018)

27 World Bank. (2013). Annual World Bank Conference on Land and Poverty 2013. A systems approach for providing legal aid for land. Retrieved from <http://www.landesa.org/wp-content/uploads/A-Systems-Approach-for-Providing-Legal-Aid-for-Land-263-Kumar.pdf> (last accessed on 4 Jan 2018)



The advantages of a blockchain-based land registration system are shown in the figure below:

Advantages of blockchain technology for land registration



Use case: Blockchain-based land registration system

Land registration management has been adopted by various governments as one of the first areas to create a blockchain proof of concept (PoC). The state of Delaware in the USA recently announced two blockchain initiatives under the banner 'Delaware is open for blockchain business', which included the archival of state records to an open distributed ledger. Other notable examples of blockchain being leveraged for land registration management are from Georgia, Ghana and Sweden.


A blockchain-based land registration system can go a long way in addressing some of the issues that exist in land registration today. A potential approach for undertaking a land registration transaction between parties over a blockchain would involve the following actors:


- **Buyer and seller**
- **Relevant land record/survey authority**
Validates the name on the deed against the buyer's identity and checks the receipt of the stamp duty. It is responsible for authenticating the identity of the buyer and seller and the ownership of the property based on the regulations prescribed by the government.
- **Office of the sub-registrar of assurances**
Validates the receipt against the stamp duty paid, property deed, property card and valid ID proof and if the process of registration was completed in a timely manner.

The approach has been shown below:


Land registration on a blockchain




 **Step 1:** Pay stamp duty through e-stamping and log in to the registration portal to upload all relevant documents (including e-stamp duty receipt).

 **Relevant land registration authority**
Step 2: Documents uploaded by the buyer and seller are verified (including relevant identification documents, the authenticity of the deed and stamp duty receipt).

 Registrar

 **Step 3:** Assess and verify all information on the form. If verified, issue certificate with digital signature.

 **Step 4:** Registration certificate is issued and the form is saved as a unique record in the blockchain.



- When a property is purchased and the requisite stamp duty is paid, a smart form (contract) is initiated after the buyer/seller uploads documents that validates his/her identity, the e-receipt of the stamp duty paid and the original property deed.
- The form is then forwarded to the relevant land record authority who authenticates the documents uploaded earlier. The authority enters a binary response (valid/invalid) against each relevant field on the smart form that corresponds to the identity of the buyer and seller and the authenticity of the relevant proofs that have been uploaded. If all fields are valid, the smart contract executes the first business rule to generate a digital property card, and this card is stamped with a unique digital signature.
- The office of the sub-registrar receives the form upon verification at the relevant land record entity. If the form is submitted in a timely manner, the second business rule is met and the form executes to register the property title digitally to the blockchain network. A digital registration certificate is issued to the buyer and the deed is now permanently stored on the blockchain.



The above approach assumes that a land or property identity is available in a trusted manner on the blockchain network or otherwise. A digital land/property ID on a blockchain is another allied use case that can be considered.



6.4. Agriculture

With 40% of the global workforce and nearly half of the Indian workforce employed in agriculture, the sector is the world's largest provider of jobs and has the potential to influence billions of lives.

Further, with increasing consumer demands for transparency in the food supply chain, producers and manufacturers struggle to provide accurate data from farm to table. Blockchain technology promises to improve traceability and transparency within agriculture value chains.

Unfair pricing due to price extortion, delayed payments, the presence of middlemen and high transaction fees are some other challenges that exist in agriculture supply chains. Additionally, food shipping and logistics are complex and

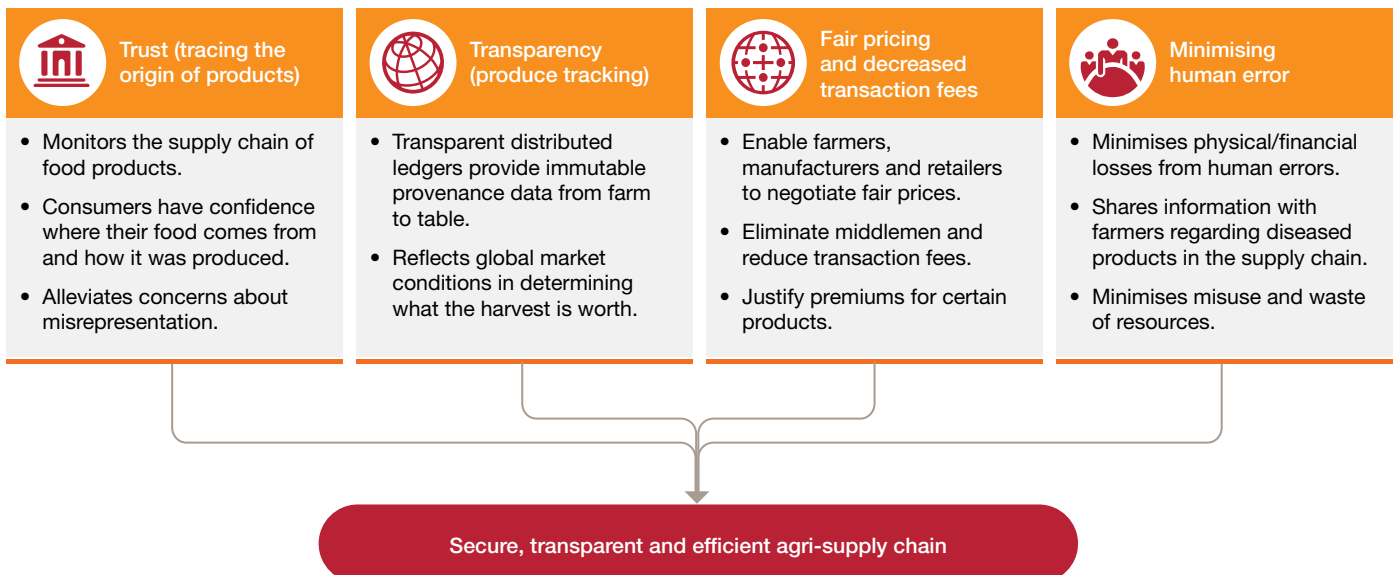
at times require intra-continent supply chains. Such supply chains involve dozens of personnel and hundreds of interactions with high probabilities for human error.²⁸

Blockchain technology has the potential to make the agri-supply chain more secure, transparent and efficient. It promises end-to-end supply chain visibility and allows one to trace the origin of a produce (provenance) and track a product/produce during its journey in a supply chain. Blockchain solutions, if implemented, may lead to the elimination of intermediaries or middlemen, thereby leading to improved pricing, decreased transaction fees, thus eliminate issues of hoarding, etc. The figure on the next page illustrates the key advantages of using a blockchain-based solution in the agri-supply chain.

²⁸ Blockchain technology. (n.d.). Agriculture. Retrieved from <http://www.ccgrouppr.com/practical-applications-of-blockchain-technology/sectors/agriculture/#section1> (last accessed on 4 Jan 2018)



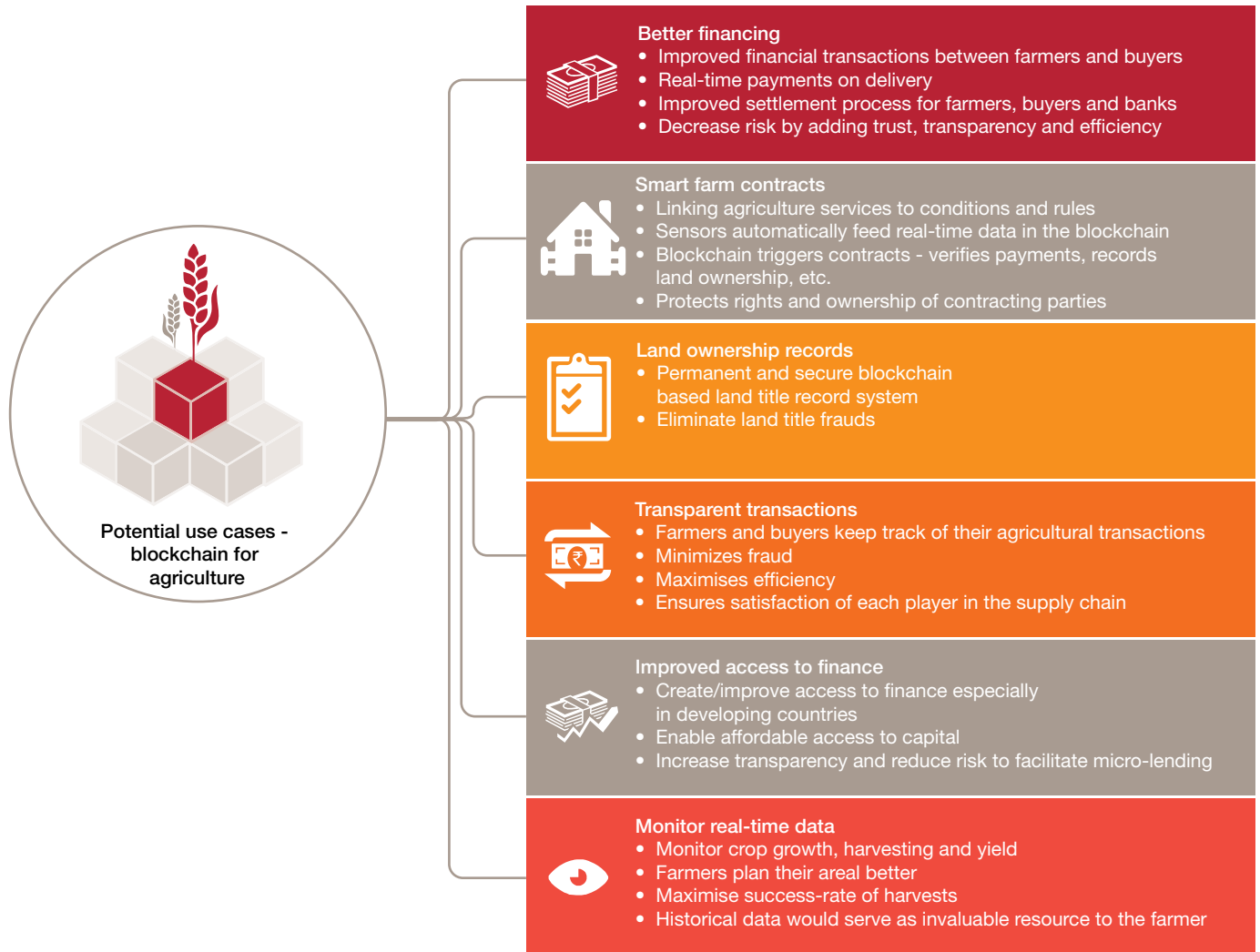
Advantages of using blockchain technology in the agriculture domain





The figure below illustrates potential uses cases of blockchain in agriculture.

Potential use cases of blockchain in the agriculture domain



With over 50% of the Indian workforce employed in the agriculture sector, the security and well-being of farmers is a matter of prime importance for the Government of India. The Pradhan Mantri Fasal Bima Yojana (PMFBY)²⁹ was launched in January 2016 and it replaced all other crop insurance schemes, integrating the benefits into one single scheme.

Under PMFBY, farmers are offered more insurance but with a lower premium amount. On top of the existing infrastructure, comprising smartphones, remote sensing technology and even drones, blockchain technology can be leveraged for quicker assessment of crop losses, assessment of compensation and the expedited settlement of claims.

29 MapsofIndia.com. (January 2016). Pradhan Mantri Fasal Bima Yojana – Highlights. Retrieved from <https://www.mapsofindia.com/my-india/government/pradhan-mantri-fasal-bima-yojana-highlights> (last accessed on 4 Jan 2018)

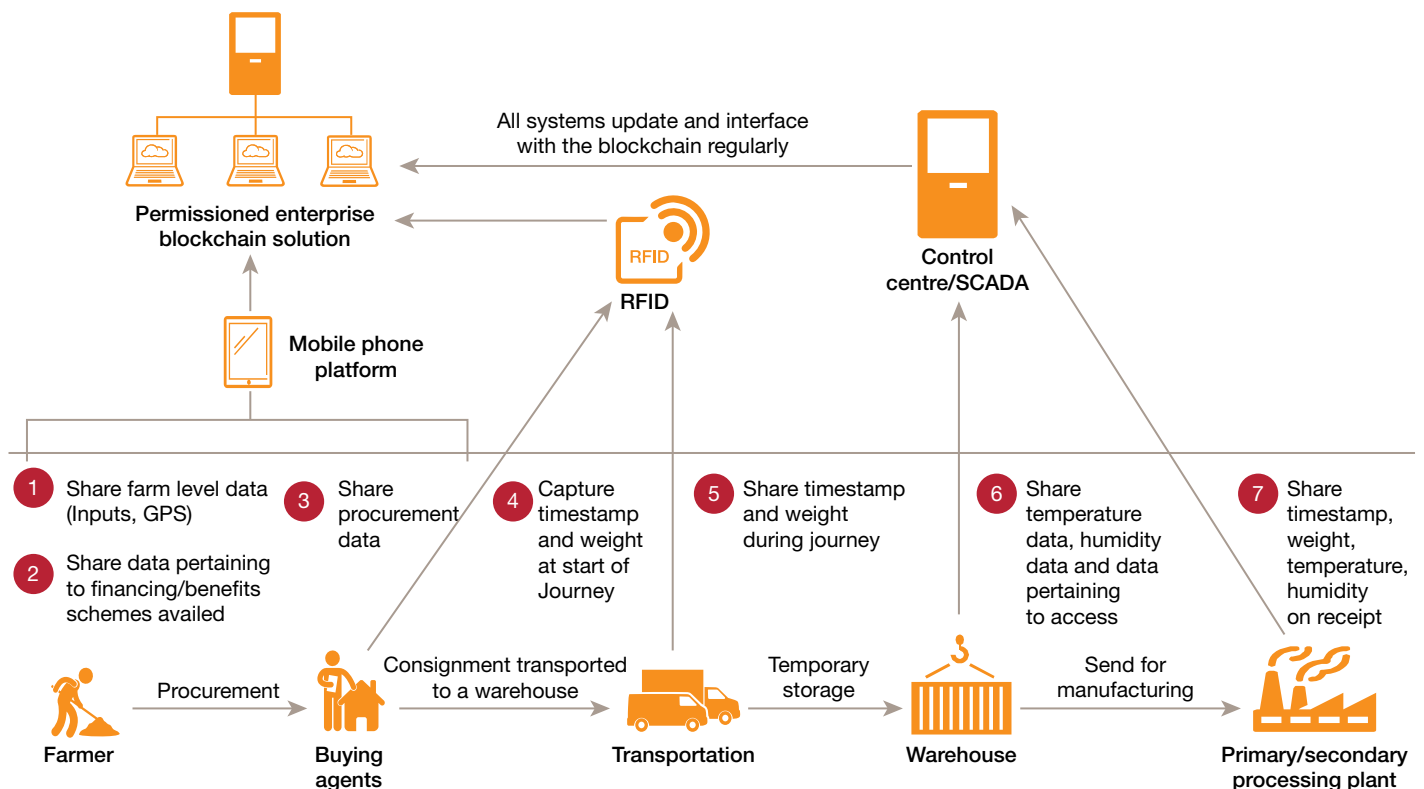
Blockchain technology can help reduce fraud in agriculture insurance, provide better provenance for organic food items, improve the food supply chain, bring disintermediation between farmers and corporates, enhance origin tracking for specialty foods and provide better price transparency

across the country for a similar type of produce to prevent exploitation of small farmers at the hands of agents and middlemen. Additionally, blockchain can also solve the problem of micro-financing for farmers by facilitating micro-lending, increasing transparency and lowering the cost of funds.³⁰

Use case: Blockchain for transparency in the supply chain³¹

Blockchain technology can be deployed to track physical products and verify attributes from origin to point of sale (PoS) to provide supply chain transparency and traceability. The figure below demonstrates a generic blockchain-based IoT solution that could effectively help maintain supply chain visibility across an agricultural value chain.

Blockchain for agriculture supply chain transparency



30 De Meijer, Carlo R.W. (23 October 2016). Blockchain: Can it be of help for the agricultural industry? Retrieved from <https://www.linkedin.com/pulse/blockchain-can-help-agricultural-industry-carlo-r-w-de-meijer/> (last accessed on 4 Jan 2018)

31 Provenance. (15 July 2016). From shore to plate: Tracking tuna on the blockchain Retrieved from <https://www.provenance.org/tracking-tuna-on-the-blockchain> (last accessed on 4 Jan 2018)





The solution deploys a blockchain application designed to work with a simple smartphone interface, either through the application itself or by linking it with existing interfaces and systems for data capture. The following steps describe one of the potential use cases of a blockchain-based supply chain:

- A farmer takes a geo-tagged image of his/her farm during harvest. The harvest is packed into gunny bags (or any other storage means) where the farmer takes a geo-tagged image of the packing area. The farmer may also share data pertaining to financing or benefit schemes using a mobile phone. The farmer then takes the gunny bags to the nearest buying agent.
- The buying agent then registers the produce of the farmer. The agent verifies and registers the produce, along with the following information:
 - Details of the farmer
 - Quantity procured
 - Other details of the produce
 - Geo-tagged image of the farm
- Once the produce is registered, a QR code is generated automatically. The buying agent prints the QR code and sticks it on the gunny bags.
- The buying agent then collates multiple registered produces and creates a consignment. Each consignment box is secured with a magnetic reed switch which generates an alarm upon being tampered with. The consignment box is secured with a thermocouple and polymeric sensor and a passive RFID tag.
- The weight of the consignment is checked before it is shipped. This weight is then fed into the blockchain by the buying agent. The consignment gets a QR code, which is indelibly linked to the QR codes of the bags in the consignment. A smart contract is initiated for the consignment.
- During transportation, the sensors track the storage conditions of the consignment. The passive RFID tag enters a time stamp at the start of the journey and a time stamp at the end of the journey at the warehouse/processing plant.
- Any violation of the expected time taken, storage conditions or tampering will be dealt with as a violation of a smart contract on the blockchain. For example, if frozen fruits are being transported and the temperature of the consignment is expected to be below zero degree Celsius at all times, a violation shall be recorded by the smart contract if at any point during the journey the temperature touches zero degree Celsius.
- Similar parameters are also captured at the warehouse before the consignment is shipped to the processing plant.
- The consignment is delivered to the processing plant. The weight of the consignment is checked and recorded in the blockchain and verified against its original weight. A smart contract is executed. If the weight of the consignment is not equal to the weight of the consignment recorded by the buying agent, the consignment is rejected.
- If no violations were raised by the smart contract and the weight matches, the consignment is accepted.
- At the primary/secondary processing plant, an employee will be able to read the QR code of each gunny bag to trace the produce to the geo-tagged farm.

Way forward

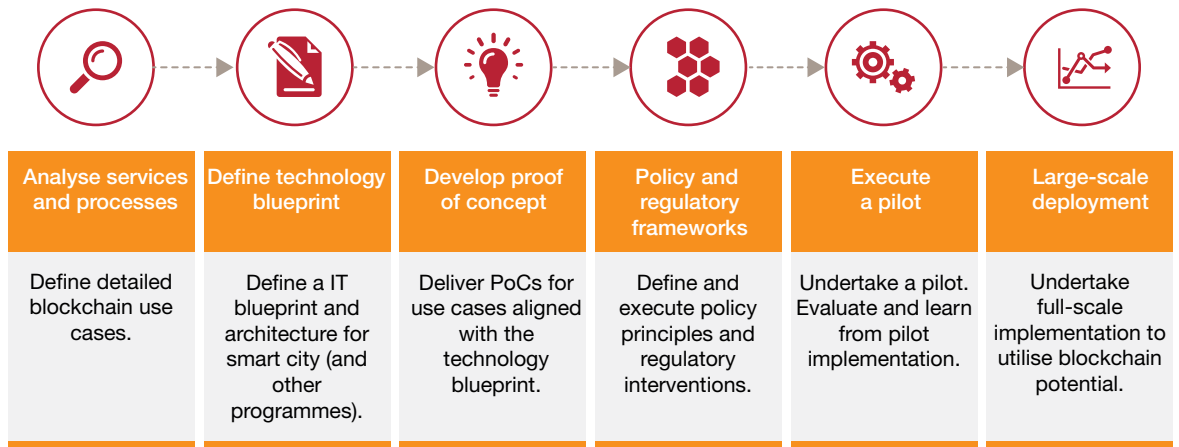
New technologies have always attracted enterprises and governments. This is largely due to their promise to improve the current way of working and service delivery, thereby leading to happier consumers and stakeholders and providing an edge over competitors, resulting in an improved brand image.

However, the large-scale implementation of a 'new technology' takes time and involves an adoption curve. Blockchain technology is also undergoing a similar adoption curve. The technology is still being tested out and new use cases are being implemented on a small scale. While most experts agree about its potential for disruption, there are a few obstacles to the successful implementation of this technology.

For the adoption of blockchain technology in the government and public sector, and specifically in the Smart Cities Mission, the technology will need to be validated, regulated and adopted.

To harness the potential of blockchain technology and reach the stage of large-scale implementation, a structured approach is needed, spanning policy, governance, ecosystem development, talent incubation, academia focus, as well as budget allocation with aligned roles and responsibilities. For governments and smart cities, the following six-phased structured approach can be adopted.

Phased approach for blockchain adoption



In addition, for smart cities to harness the potential of blockchain technology, it needs to be adopted by the Smart Cities Mission. The development of all smart cities needs to be viewed from the lens of blockchain technology to ascertain if blockchain-based implementation would be more advantageous over traditional technologies.

In conclusion, there is a technology disruption underway which has the potential to make our cities smart. This is a once-in-a-generation opportunity and it is incumbent on us to seize it.



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