Analysing Non-Financial Use Cases of Blockchain in India

Working Paper

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By **Vipul Kharbanda and Aman Nair**

The Centre for Internet and Society, India

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Introduction

Ever since its initial conceptualisation in 2009, blockchain technology has been synonymous with financial products and services - most notably crypto-assets like Bitcoin. However, while often associated with the financial sector, blockchain technology represents an opportunity for multiple industries to reinvent and improve their legacy processes. In India, the 2020 discussion Paper on Blockchain Technology by the Niti Aayog as well as the National Blockchain Strategy of 2021 by the Ministry of Electronics and Information Technology have attempted to articulate this opportunity. These documents examine the potential benefits that would arise from blockchain's introduction across multiple non financial sectors.

This policy paper looks to examine three specific use cases mentioned in the abovementioned government documents: Land record management, certification verification and pharmaceutical supply chain management. We look to provide an overview of what blockchain technology is and document the ongoing attempts to integrate blockchain technology into the aforementioned fields. We also assess the possible costs and benefits associated with blockchain's introduction and look to draw insights from instances of such integration in other jurisdictions.

1. The Technology

1.1 What is Distributed Ledger Technology and what is a Blockchain?

There appears to be a lack of academic consensus on the exact definition of the term Distributed Ledger Technology (DLT). As Rauchs et al observe,[1] existing literature on the subject has failed to produce a singular definition for Distributed Ledger Technology. As a result, the term has come to denote a number of similar and related technologies and concepts.

In attempting to therefore define the term, they identified a minimum number of necessary characteristics that all DLTs possess.[2] This leads to DLT being defined as "*a system of electronic records that enables a network of independent participants to*

[1] Michel Rauchs et al., "Distributed Ledger Technology Systems: A Conceptual Framework," SSRN Scholarly Paper (Rochester, NY: Social Science Research Network, August 13, 2018), https://doi.org/10.2139/ssrn.3230013.

[2] Id, pg 22

establish a consensus around the authoritative ordering of cryptographically-validated ('signed') transactions. These records are made persistent by replicating the data across multiple nodes, and tamper-evident by linking them by cryptographic hashes. The shared result of the reconciliation/consensus process - the 'ledger' - serves as the authoritative version for these records."[3]

Blockchain is a form of DLT that was first proposed in 2008 by Satoshi Nakamoto (the pseudonymous founder of blockchain), and first operationalised in 2009.[4] A blockchain can be defined as "*a public ledger, in which all committed transactions are stored in a chain of blocks. This chain continuously grows when new blocks are appended to it. The blockchain technology has the (sic.) key characteristics, such as decentralisation, persistence, anonymity and audibility*."[5]

The blockchain system is composed of the following elements:

a. **Nodes**

   A node is any device that possesses a complete record of all transactions undertaken on the blockchain.[6] Nodes on a blockchain are interconnected and share data between themselves. They perform three key functions: verify the validity of all blocks on the blockchain, maintain a record of all transactions and also transmit information between themselves.[7]

b. **Blocks**

   Blocks are the individual components that comprise the blockchain. A block consists of a block header as well as the block body.[8] The block header comprises of the block parameter, the hash of the previous block, the timestamp, nonce, nbits and Merkle root. The block parameter determines the rules by which blocks are validated on the blockchain. The nonce is a randomly generated one-time use number that is utilised to validate the hash and achieve consensus between the blocks. Nbits are the current hashing target in a compact format. The Merkle root is

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[3] Id, pg 24

[4] Satoshi Nakamoto, "Bitcoin: A Peer-to-Peer Electronic Cash System," *Manubot* (Manubot, November 20, 2019), https://git.dhimmel.com/bitcoin-whitepaper/.
Zibin Zheng et al., "Blockchain Challenges and Opportunities: A Survey," *International Journal of Web and Grid Services* 14, no. 4 (January 1, 2018): 352–75, https://doi.org/10.1504/IJWGS.2018.095647.

[5] Zibin Zheng et al., "Blockchain Challenges and Opportunities: A Survey," *International Journal of Web and Grid Services* 14, no. 4 (January 1, 2018): 352–75, https://doi.org/10.1504/IJWGS.2018.095647.

[6] Jimi S, "Blockchain: What Are Nodes and Masternodes?," *Medium* (blog), October 14, 2020, https://medium.com/coinmonks/blockchain-what-is-a-node-or-masternode-and-what-does-it-do-4d9a4200938f.

[7] Id.

[8] Zibin Zheng et al., "Blockchain Challenges and Opportunities: A Survey," *International Journal of Web and Grid Services* 14, no. 4 (January 1, 2018): 352–75, https://doi.org/10.1504/IJWGS.2018.095647.

the hash of all hashes related to all transactions on the blockchain.
The block body contains all the transactions that are stored on the blockchain as well as a counter for the transactions.

c. Consensus mechanism

Swanson defines a consensus mechanism as, "*the process in which a majority (or in some cases all) of network validators come to agreement on the state of a ledger. It is a set of rules and procedures that allows maintaining coherent set of facts between multiple participating nodes.*"[9]Consensus mechanisms can take a multitude of forms such as proof of work, proof of stake, proof of capacity, delegated proof of stake and practical byzantine fault tolerance.[10]

d. Mining process

Mining is the process whereby new blocks are added to the blockchain.[11] When a new transaction is initiated, a call is sent across the blockchain to begin the process of converting it into a new block.[12] The new transaction must then be validated through the use of the blockchain's consensus mechanism, after which it will be added as a new block to the blockchain. The specificity of the mining process is, therefore, contingent upon the consensus mechanism that is being employed by the blockchain, with the most common conception relating to the proof of work mechanism employed by entities such as Bitcoin.

e. Forks

Sometimes during the mining process, multiple nodes can find the appropriate

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[9] Tim Swanson, "Consensus-as-a-Service: A Brief Report on the Emergence of Permissioned, Distributed Ledger Systems," April 6, 2015, http://www.ofnumbers.com/wp-content/uploads/2015/04/Permissioned-distributed-ledgers.pdf *in* Michael Nofer et al., "Blockchain," *Business & Information Systems Engineering* 59, no. 3 (June 1, 2017): 183–87, https://doi.org/10.1007/s12599-017-0467-3.

[10] Arthur Gervais et al., "On the Security and Performance of Proof of Work Blockchains," in *Proceedings of the 2016 ACM SIGSAC Conference on Computer and Communications Security*, CCS '16 (New York, NY, USA: Association for Computing Machinery, 2016), 3–16, https://doi.org/10.1145/2976749.2978341.
Zibin Zheng et al., "Blockchain Challenges and Opportunities: A Survey," *International Journal of Web and Grid Services* 14, no. 4 (January 1, 2018): 352–75, https://doi.org/10.1504/IJWGS.2018.095647.
Iddo Bentov et al., "Proof of Activity: Extending Bitcoin's Proof of Work via Proof of Stake [Extended Abstract]," *ACM SIGMETRICS Performance Evaluation Review* 42, no. 3 (December 8, 2014): 34–37, https://doi.org/10.1145/2695533.2695545.
"Proof of Stake vs. Delegated Proof of Stake," *Cryptopedia* (blog), April 30, 2021, https://www.gemini.com/cryptopedia/proof-of-stake-delegated-pos-dpos.
Barbara Liskov and Miguel Castro, "Practical Byzantine Fault Tolerance," *OSDI* 99, no. 1999 (1999): 173–86.

[11] Ittay Eyal and Emin Gun Sirer, "Majority Is Not Enough: Bitcoin Mining Is Vulnerable," *ArXiv:1311.0243 [Cs]*, November 15, 2013, http://arxiv.org/abs/1311.0243.

[12] Abdul Jabbar and Samir Dani, "Investigating the Link between Transaction and Computational Costs in a Blockchain Environment," *International Journal of Production Research* 58, no. 11 (June 2, 2020): 3423–36, https://doi.org/10.1080/00207543.2020.1754487.

nonce simultaneously, leading to the creation of multiple valid blocks.[13] This is known as a fork in the blockchain. New blocks are then added to one of the two new blocks, causing the other block to be 'orphaned.'[14] A fork can also occur when the protocol of the blockchain is changed. If there is no consensus on the protocol change then the blockchain will fork into two new blockchains.[15] Blockchain forks can be soft (when they are backwards compatible) or hard (not backwards compatible).[16]

Blockchains can be categorised into 3 types on the basis of who controls the consensus mechanism: private, public and consortium.

a. Public blockchains are those where any individual or entity can read and participate in the consensus procedure on the blockchain.[17]
b. A private blockchain is one where the writing procedure is controlled by a centralised entity and not open to the public.[18]
c. In a consortium blockchain, the consensus procedure is controlled by a select number of nodes.[19]

1.2 Benefits and Limitations of Blockchain

With blockchain being touted as a solution to a number of existing legacy problems, it is important that one examines the potential benefits and limitations associated with the technology.

The key benefits of blockchain technology are as follows:

a) Decentralisation

Since blockchain technology does not rely on any central authority to validate transactions, it can be operational in situations wherein individual nodes are

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[13] Zibin Zheng et al., "Blockchain Challenges and Opportunities: A Survey," *International Journal of Web and Grid Services* 14, no. 4 (January 1, 2018): 352–75, https://doi.org/10.1504/IJWGS.2018.095647.

[14] Amy Castor, "A Short Guide to Bitcoin Forks," *CoinDesk* (blog), March 27, 2017, https://www.coindesk.com/markets/2017/03/27/a-short-guide-to-bitcoin-forks/.

[15] Id.

[16] Id.

[17] Dominique Guegan, "Public Blockchain versus Private Blockchain," CES Working Paper, April 2017, https://halshs.archives-ouvertes.fr/halshs-01524440.
Vitalik Buterin, "On Public and Private Blockchains," *Ethereum Foundation Blog* (blog), August 7, 2015, https://blog.ethereum.org/2015/08/07/on-public-and-private-blockchains/.

[18] Id.

[19] Vitalik Buterin, "On Public and Private Blockchains," *Ethereum Foundation Blog* (blog), August 7, 2015, https://blog.ethereum.org/2015/08/07/on-public-and-private-blockchains/.

damaged or unavailable.[20]

b) **Authenticity and persistence**
Since all transactions on the blockchain are recorded and validated throughout the entire network it is difficult to either falsify or lose the list of all transactions.[21]

c) **Anonymity**
Individuals do not need to use personal details or identifying information in order to interact with the blockchain. Rather, they merely need to have access to their generated blockchain address.[22]

d) **Auditability**
The nature of the consensus mechanism as well as the timestamp associated with each transaction can allow for transactions on the blockchain to be tracked and verified (though it can only be tracked to a blockchain address, the details of the individual or entity that possesses that address will generally be unavailable).[23]

Despite these benefits, blockchain technology does come with its fair share of limitations.

a. **No transactional privacy**
The auditability associated with blockchain ensures that while individuals might be able to make their identity private, they are generally unable to achieve privacy related to individual transactions.[24]

b. **Environmental costs**
The decentralisation of blockchain requires that a significant amount of computing power is required to operate the network - though the extent of the required power is contingent on the consensus mechanism and mining process used. This

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[20] Zibin Zheng et al., "Blockchain Challenges and Opportunities: A Survey," *International Journal of Web and Grid Services* 14, no. 4 (January 1, 2018): 352–75, https://doi.org/10.1504/IJWGS.2018.095647.
Michael Nofer et al., "Blockchain," *Business & Information Systems Engineering* 59, no. 3 (June 1, 2017): 183–87, https://doi.org/10.1007/s12599-017-0467-3.

[21] Zibin Zheng et al., "Blockchain Challenges and Opportunities: A Survey," *International Journal of Web and Grid Services* 14, no. 4 (January 1, 2018): 352–75, https://doi.org/10.1504/IJWGS.2018.095647.
Laurie Hughes et al., "Blockchain Research, Practice and Policy: Applications, Benefits, Limitations, Emerging Research Themes and Research Agenda," *International Journal of Information Management* 49 (December 1, 2019): 114–29, https://doi.org/10.1016/j.ijinfomgt.2019.02.005.

[22] Id.

[23] Id.

[24] Laurie Hughes et al., "Blockchain Research, Practice and Policy: Applications, Benefits, Limitations, Emerging Research Themes and Research Agenda," *International Journal of Information Management* 49 (December 1, 2019): 114–29, https://doi.org/10.1016/j.ijinfomgt.2019.02.005.
Zibin Zheng et al., "Blockchain Challenges and Opportunities: A Survey," *International Journal of Web and Grid Services* 14, no. 4 (January 1, 2018): 352–75, https://doi.org/10.1504/IJWGS.2018.095647.

can result in significant environmental costs as is the case in instances such as Bitcoin.

c. **Regulatory difficulties**
The decentralised nature of blockchain creates a situation where lawmakers may find it difficult to apply legal and regulatory standards and protections to their functioning. Given that blockchain has been touted for fields such as finance and banking, this lack of regulatory applicability can be a significant barrier.

d. **Possibility of collusion**
Despite being decentralised, a blockchain can be susceptible to manipulation by a group of colluding miners. Such collusion and manipulation can take a multitude of forms such as the 51% attack, selfish mining, and stubborn mining, to name a few.[25]

1.3 Smart Contracts

Cryptographer Nick Szabo initially conceived of a smart contract as "*a set of promises, specified in digital form, including protocols within which the parties perform on (sic.) the other promises.*"[26]

The emergence of blockchain technology has found itself intertwined with a parallel movement towards blockchain-based smart contracts. In this context, Wang et al. define smart contracts as "*self-executing contracts with the terms of the agreement between interested parties. The contracts are written in the form of program codes that exist across a distributed, decentralized blockchain network.*"[27]

Much like a regular contract, the parties involved must reach an agreement on the terms of the contract, potential breaches and the liability involved. It is then deployed on the blockchain as a smart contract that is executed automatically as certain conditions are

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[25] *Explanations of the mentioned strategies can be found at the following sources:*
Zibin Zheng et al., "Blockchain Challenges and Opportunities: A Survey," *International Journal of Web and Grid Services* 14, no. 4 (January 1, 2018): 352–75, https://doi.org/10.1504/IJWGS.2018.095647.
Ittay Eyal and Emin Gun Sirer, "Majority Is Not Enough: Bitcoin Mining Is Vulnerable," *ArXiv:1311.0243 [Cs]*, November 15, 2013, http://arxiv.org/abs/1311.0243.
K. Nayak et al., "Stubborn Mining: Generalizing Selfish Mining and Combining with an Eclipse Attack," in *2016 IEEE European Symposium on Security and Privacy (EuroS P)*, 2016, 305–20, https://doi.org/10.1109/EuroSP.2016.32.

[26] Giulio Caldarelli, "Understanding the Blockchain Oracle Problem: A Call for Action," *Information* 11, no. 11 (November 2020): 509, https://doi.org/10.3390/info11110509.

[27] Shuai Wang et al., "An Overview of Smart Contract: Architecture, Applications, and Future Trends," in *2018 IEEE Intelligent Vehicles Symposium (IV)*, 2018, 108–13, https://doi.org/10.1109/IVS.2018.8500488.

achieved.[28] The smart contracts are attached to the blockchain through program codes which are then verified across the nodes of the blockchain.[29]

One of the key elements required in the execution of a smart contract is the oracle or external data validation source. An oracle is a system or entity that provides the blockchain with external information or data.[30] In the case of a smart contract, an oracle would notify the blockchain of the fulfilment of the requisite conditions, thereby leading to the contract being executed.

As oracles are not distributed across the blockchain, they represent a centralised point of failure that can be exploited. Moreover, since oracles provide non-deterministic data, their reliability requires an inherent level of trust, thereby mitigating the blockchain's effectiveness as a trustless peer-to-peer network.[31]

2. Non-Financial Use Cases of Blockchain

Since 2019, the government of India has released a number of reports on blockchain technology as well as virtual currencies starting with the Inter-Ministerial Committee Report on Virtual Currencies (2019),[32] the Whitepaper by the NIC on Blockchain for Government (2020),[33] the Discussion Paper by the Niti Aayog titled Blockchain: The India Strategy, Part 1 (2020)[34] as well as the National Strategy on Blockchain by the Ministry of

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[28] Id.

[29] Id.

[30] Giulio Caldarelli, "Understanding the Blockchain Oracle Problem: A Call for Action," *Information* 11, no. 11 (November 2020): 509, https://doi.org/10.3390/info11110509.

[31] Id.
Alexander Egberts, "The Oracle Problem - An Analysis of How Blockchain Oracles Undermine the Advantages of Decentralized Ledger Systems," SSRN Scholarly Paper (Rochester, NY: Social Science Research Network, December 12, 2017), https://doi.org/10.2139/ssrn.3382343.

[32] Report of Inter-Ministerial Committee on Virtual Currencies, Department of Economic Affairs, Ministry of Finance, India, dated February 28, 2019, available at https://dea.gov.in/sites/default/files/Approved%20and%20Signed%20Report%20and%20Bill%20of%20IMC%20on%20VCs%2028%20Feb%202019.pdf

[33] Blockchain for Government, National Informatics Centre, available at https://blockchain.gov.in/Whitepaper_30jan.pdf

[34] *Blockchain The India Strategy Part I*, NITI Aayog (January 2020), https://www.niti.gov.in/sites/default/files/2020-01/Blockchain_The_India_Strategy_Part_I.pdf.

Electronics and Information Technology (2021)[35]. These papers discuss a number of pilot projects that have been undertaken utilising blockchain technology. In this part of the paper, we shall discuss some of the most important use cases of Blockchain technology in non-financial services as described in the abovementioned government documents.

2.1 Land Records

The domain of Land Record Management systems is one of the areas where the utilisation of blockchain technology can have a tremendous impact and "can facilitate the functioning of land markets in developing countries as well as diminish the threat of losing land rights for vulnerable communities and women".[36]

2.1.1 Indian context

The ownership of property in India is proved through a system of "Record of Rights" i.e. a deeds registration system where the deed transferring the title of the land is registered with a centralised registrar. This is opposed to a system of title by registration, such as the Torrens system[37] wherein the state maintains a register of landholdings and the title of the land conclusively belongs to the person who is recorded as the title holder in the said register. In India, land ownership is primarily established through a registered sale deed and the chain of documents that provide proof of the transfer of ownership of the land over the years to the current owner. However, any of these intermediate transactions are subject to be challenged since the job of the registrar is only to provide proof of the authenticity of the document which is registered and it does not verify the actual ownership of the land.[38]

Major Problems in the Current System

It is a commonly accepted fact that the system of land transfers and land records in most parts of India is cumbersome and perhaps outdated leading to a large number of problems such as:

a. *Poor maintenance of records*

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[35] National Strategy on Blockchain, Ministry of Electronics and Information Technology, https://negd.gov.in/sites/default/files/NationalStrategyBCT_%20Jan2021_final_0.pdf

[36] Desiree Daniel and Chinwe Ifejika Speranza, 'The Role of Blockchain in Documenting Land Users' Rights: The Canonical Case of Farmers in the Vernacular Land Market', *Frontiers in Blockchain* 3 (2020), https://www.frontiersin.org/article/10.3389/fbloc.2020.00019.

[37] Patton, R.G., "The Torrens System of Land Title Registration" (1935). Minnesota Law Review. 2106. This system is used in a number of countries such as Australia, Canada, New Zealand, etc.

[38] Blockchain for Government, National Informatics Centre, January, 2020, p. 36, available at https://blockchain.gov.in/Whitepaper_30jan.pdf

Traditionally land records relating to ownership, possession and transfer have been maintained by Registrars, Patwaris and other Revenue Officials. Due to the lack of a title registry relating to land, the buyer often has to go through a large number of documents, which are often in dilapidated condition and illegible, to establish the nature of the title of the seller. On top of that records may at times be destroyed by fire, water damage, etc. or even due to deliberate corruption by officials.[39] Such a process is inefficient, time-consuming and often deters genuine investors from investing in land, thereby depriving the owner from unlocking its true potential.

b. *Non-compatibility of interdepartmental data*
Different types of land records are kept by different departments, for example, registration of land transfer is managed by the Department of Stamps and Registration, while land records for revenue collection are managed by the Revenue Department. The departments often have different versions of the land details stored with them which leads to confusion requiring updating of records before any transactions relating to the land can be completed.[40] Further, every state has its own format and mode of recording land transfers which makes it difficult to obtain uniform records of the land.[41]

c. *Tampering of documents*
Properties are sometimes sold on the basis of fraudulent documents obtained by tampering with the original documents. In this manner, a single property may be sold to multiple users since the current system does not share real-time data with key shareholders.[42]

d. *Transfer of ownership through means other than sale deeds*
It must be pointed out that sale deeds or transfer deeds are not the only means whereby the title to land may pass from one person to another. A title may be acquired through inheritance, relinquishment, family partition, etc. Such transfers of ownership need to be established through other documents, all of which may not be available at a centralised repository, while others (such as oral family settlements) may not require any documents at all. Since the onus to verify the

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[39] Blockchain: The India Strategy, Draft Discussion Paper, Niti Aayog, January 2020, p. 32.

[40] Blockchain for Government, National Informatics Centre, January, 2020, p. 36, available at https://blockchain.gov.in/Whitepaper_30jan.pdf

[41] Vishnu Chandra & Baladevan Rangaraju, “Blockchain for Property: A Roll Out Road Map for India”, India Institute, p. 14, available at https://www.academia.edu/35501318/BLOCKCHAIN_FOR_PROPERTY_A_Roll_Out_Road_Map_for_India

[42] Vishnu Chandra & Baladevan Rangaraju, “Blockchain for Property: A Roll Out Road Map for India”, India Institute, p. 14, available at https://www.academia.edu/35501318/BLOCKCHAIN_FOR_PROPERTY_A_Roll_Out_Road_Map_for_India

documents is usually on the purchaser, the process of verification often proves to be cumbersome and costly and may still not be completely fraud-proof.[43]

2.1.2 Proposed System to Deploy Blockchain Technology

The Centre of Excellence for Blockchain Technology (CoEBCT) has proposed a system for utilising blockchain technology in land records. The CoEBCT is the centre established by the National Informatics Centre (NIC) to operate as a coordinated, interoperable blockchain ecosystem around the nation, allowing all partners to benefit from shared learning, experiences and resources. It is the job of the CoEBCT to collaborate with global experts to lead the development and implementation of innovative blockchain solutions from proof of concept to production. The system proposed by the CoEBCT, which is the same as the system proposed by the NIC in its Whitepaper "Blockchain for Government" released in January 2020, is briefly described below:[44]

- Since blockchain technology is dependent upon the existence of verified and digitized land records and considering that land is one of the most important and valuable assets, land records data needs to be accurately stored in the blockchain as a starting point, i.e. the existing history of transactions on every piece of land will need to be inserted into the blockchain after approval by Revenue authorities in the relevant State. The data thus approved will then have to be digitally signed and stored thus forming the starting point for any future transactions relating to any piece of land. The certificates that are issued by the Revenue Department, will be stored in the blockchain and can be used by other agencies like banks, other government departments, etc. for verification during a transaction on a particular piece of land.

- The transactions related to change of ownership through sale, loan, mortgage, release of mortgage, and crop updating are initiated by other departments. During the initiation of such transactions, the land details shall be verified using the blockchain data. After the approval of the transaction in the respective database such as the completion of the deed of registration/approval of the loan by the bank, the details of this latest transaction shall be updated and stored in the blockchain for future verification.

- The Registration Department will fetch details with respect to a particular survey number from the blockchain and ensure that the ownership of the land parcel indeed rests with the prospective seller before initiating a sale. After obtaining the purchaser's and seller's signatures on the sale deed, the scanned document shall be updated in the blockchain to create a block. Likewise, the chain of blocks is created every time the property title is changed from one person to another.

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[43] Blockchain: The India Strategy, Draft Discussion Paper, Niti Aayog, January 2020, p.31.

[44] Land Records', Centre of Excellence in Blockchain Technology, accessed 28 June 2022, https://blockchain.gov.in/landrecords.html.

- By implementing smart contracts, certain events such as registration of the land may be able to automatically initiate the mutation request in the land records, the approval of the loan by the bank can update the rights and liabilities, and crop details updating can trigger the updating of cultivators and crop details in the Records of Rights, Tenancy and Crops (RTC). Smart contracts can also facilitate the payment of subsidies to farmers for failure of crops. In cases when the entitlement is only for certain types of farmers, the eligibility can be ascertained from the blockchain.

2.1.3 Advantages of the Proposed System

As per the CoEBCT, the system described above would have a number of advantages over the existing system of keeping land records, some of which are given below:[45]

a) Accessible records
The availability of data in a central location that can be accessed by multiple departments would enable faster disposal of requests for a subsidy, mutation, etc. The facilities provided to the farmer from the agriculture / Horticulture departments / Animal Husbandry department when recorded in the blockchain will facilitate these departments to ensure that the same benefit / multiple benefits do not reach the same farmer multiple times or that a single person might not receive multiple benefits as per the terms & conditions laid down.

b) No need for third party
There would be no need for a trusted authority to provide attested copies of documents.

c) Record veracity
Owners can be assured that their land ownership cannot be changed by spurious persons. The availability of a documented chain will eliminate registration based on bogus or tampered documents.

d) Updating details for loans
Farmers would be able to obtain loans quickly and updating of the details related to liability in the Record of Rights can be done as soon as the farmer repays the loan. This would facilitate the farmer to avail of other benefits/services.

e) Publicly available information
Blockchain data of property registration will be made available in the workflow system of the Registration software as well as to the public for verification. This will provide complete details of the property chain right from the first purchaser to the latest one. The purchaser need not depend on any non-reliable

[45] Id.

personnel/agency to verify the authenticity of the document provided by the seller.

Apart from the above, the Niti Aayog suggests that employing such a system could not only pave the way for a "conclusive titling" akin to the Torrens system but also stimulate investments in the land as an asset class for companies creating a seamless marketplace for land transactions thereby unlocking economic value and liquidity.[46]

2.1.4 International use cases of blockchain in Land record management

Internationally, many jurisdictions have been looking into the effectiveness of land record management arrangements,[47] some of these are discussed below briefly:

a. Sweden

In 2016, Lantmäteriet, the official Swedish Land Registry collaborated with a telecom company and a blockchain startup to explore the potential of blockchain technology in the real estate sector in Sweden and began building a prototype.[48] Later in the same year, a pilot project was initiated on the basis of this prototype and with the involvement of other actors.[49] This phase of the project concluded in March 2017 and produced a report in addition to a fully functional technical solution[50] that was ready to be implemented in the actual system. It was deduced in the report that the utilisation of blockchain in areas such as land registries can lead to a reduction in costs, improvement in authenticity and security of information, and overall economic growth in the country.[51]

The project was initiated with the goal of identifying an efficient, cost-effective, secure, and trusted system for land registration in the country as the existing system was noticed to be lengthy and time-consuming, and only involved the land registry at a late stage.[52] It sought to eliminate the delays in the process along with the requirement of physical documentation. While the new system is expected to speed up and increase the authenticity of the process, there have been no new

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[46] Blockchain: The India Strategy, Draft Discussion Paper, Niti Aayog, January 2020, p. 33,34.

[47] *Id.*

[48] Juliet McMurren, Andrew Young, and Stefaan Verhulst, 'Addressing Transaction Costs Through Blockchain and Identity in Swedish Land Transfers' (GovLab, October 2018), https://blockchan.ge/blockchange-land-registry.pdf.

[49] *Id.*

[50] 'The Land Registry in the Blockchain - Testbed' (Lantmäteriet, March 2017), https://static1.squarespace.com/static/5e26f18cd5824c7138a9118b/t/5e3c35451c2cbb6170caa19e/1581004119677/Blockchain_Landregistry_Report_2017.pdf.

[51] Id.

[52] Id.

developments on its real-world deployment and the scalability of the technology is yet to be tested.

b. Ukraine

In 2017, the Ukrainian government unveiled plans to launch a trial project on the utilisation of blockchain in the land registry system.[53] This project represented the second instance wherein blockchain technology was integrated into an existing public service. The government partnered with the blockchain firm Bitfury, and non-governmental organisation Transparency International for implementing and overseeing the project.[54]

As part of the project, every transaction that was to be logged in the existing land cadastre would now be recorded into a blockchain. All land titles are now accompanied by a QR code that encrypts various details about the land such as the size of the property, the location and who owns it.[55]

c. Georgia

Georgia launched its pilot programme in 2016 for a blockchain-based land titling system, borne out of a collaboration between Bitfury Group, the National Agency of the Public Registry (NAPR), and the Blockchain Trust Accelerator.[56] Unlike in other countries, this was not a proprietary blockchain registration system. Rather what "Bitfury created was a Blockchain-based timestamping layer on top of the NAPR's existing digital land registry system."[57] Blockchain integration was intended to add a layer of immutability and allow for document owners to verify the time of the receipt as well as to demonstrate that it was authenticated by the NAPR.[58]

d. Brazil

Land management in Brazil does not operate as an integrated system; rather land administration is divided across various public institutions and is contingent on a multitude of factors including the type of land and its proposed use.[59] In 2017, the

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[53] Taras Bachynskyy and Roman Radeiko, "Legal Regulations of Blockchain and Cryptocurrency in Ukraine," *Hungarian Journal of Legal Studies* 60, no. 1 (March 1, 2019): 3–17, https://doi.org/10.1556/2052.2019.60102.

[54] Id.

[55] Id.

[56] Qiuyun Shang and Allison Price, "A Blockchain-Based Land Titling Project in the Republic of Georgia: Rebuilding Public Trust and Lessons for Future Pilot Projects," *Innovations: Technology, Governance, Globalization* 12, no. 3–4 (January 1, 2019): 72–78, https://doi.org/10.1162/inov_a_00276.

[57] Id.

[58] Id.

[59] Victoria Lemieux, Daniel Flores, and Claudia Lacombe, "Title and Code: Real Estate Transaction Recording in the Blockchain in Brazil (RCPLAC-01)-Case Study 1 Document Control Version History Version Date By Version Notes," 2018, https://doi.org/10.13140/RG.2.2.10569.85606.

real estate registry office of the municipalities of Pelotas and Morro Redondo announced a pilot programme with the private corporation Ubitquity that looked to utilise blockchain technology to streamline the land registration system in the regions.[60] Blockchain technology was proposed as a means of validating the authenticity of information related to real estate, such as land ownership. The project looks to develop "*a parallel blockchain platform to replicate the existing legal structure of property recording and transfer processes, with the use of the Software as a Service business model to record land transactions on behalf of companies and government agencies.*"[61]

e. Russia

The Ministry of economic development and trade of Russia is currently developing a system whereby all the details of all land titles will be recorded and stored on a blockchain.[62] The project looks to reduce costs associated with traditional land management and registration processes.[63]

f. Canada

The Land Titles and Survey Authority (LTSA) of British Columbia has partnered with the Digital Identity and Authentication Council of Canada (DIACC) and IdentityNorth (IDN) to integrate blockchain technology as an integral part of the land registration system.[64] Part of this project also involves a scoping and assessment study undertaken by the University of British Columbia on the potential benefits, drawbacks and challenges associated with the implementation of blockchain technology as a part of a land management framework.[65]

g. Netherlands

In 2018, the dutch land registry (called Kadester) implemented a new land registration programme that utilises both blockchain and AI.[66] The system is one of

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[60] Id.

[61] Maria Kaczorowska, "Blockchain-Based Land Registration: Possibilities and Challenges," *Masaryk University Journal of Law and Technology* 13, no. 2 (2019): 339–60.

[62] Mohammed Shuaib et al., "Blockchain-Based Framework for Secure and Reliable Land Registry System," *TELKOMNIKA (Telecommunication Computing Electronics and Control)* 18, no. 5 (October 1, 2020): 2560–71, https://doi.org/10.12928/telkomnika.v18i5.15787.

[63] Hartmut Müller and Markus Seifert, "Blockchain, a Feasible Technology for Land Administration?," 2019.

[64] Mohammed Shuaib et al., "Blockchain-Based Framework for Secure and Reliable Land Registry System," *TELKOMNIKA (Telecommunication Computing Electronics and Control)* 18, no. 5 (October 1, 2020): 2560–71, https://doi.org/10.12928/telkomnika.v18i5.15787.

[65] "BC Land Title & Survey Authority (LTSA) Digital ID Design Challenge (DIAC)," *The University of British Columbia* (blog), accessed February 23, 2022, https://blockchain.ubc.ca/research/bc-land-title-survey-authority-ltsa-digital-id-design-challenge-diac.

[66] Mohammed Shuaib et al., "Blockchain-Based Framework for Secure and Reliable Land Registry System," *TELKOMNIKA (Telecommunication Computing Electronics and Control)* 18, no. 5 (October 1, 2020): 2560–71, https://doi.org/10.12928/telkomnika.v18i5.15787.

a multitude of blockchain-based governance initiatives adopted by the state as part of its 'blockchain pilots programme.'[67] Blockchain technology is envisioned in this context as a tool to improve the efficiency and flexibility of the dutch land registry.[68]

h. Ghana

Blockchain technology has been suggested as a means of solving some of the issues caused due to Ghana's dual-natured land market, i.e, corruption, double ownership, lack of verifiable documentation, etc.[69]

As such, the country has seen multiple attempts at integrating blockchain technology into its land management and registration processes. The first of these was the Bitland Land Registry System which was created out of a collaboration between the state and Bitland - a non-profit organisation working on addressing concerns relating to property using blockchain technology.[70] Following this, the group BenBen has looked to develop a digital registry of all land registrations that is based on the Ethereum blockchain.[71] In 2018, a memorandum of understanding was signed between Ghana and IBM on the development of a blockchain-based land registration system.[72]

2.1.5 Challenges faced in the implementation of such a system

Insights from other jurisdictions have pointed to the fact that the implementation of blockchain into a land records management system comes with obstacles that must be overcome. These are as follows:

a. Dispute Free Titles

The immutable nature of the blockchain creates a need for a single source of truth to be determined before the data is put on the blockchain. In order to ensure the

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[67] Priyankar Bhunia, "How the Dutch Government Is Exploring Blockchain Use Cases through Many Concurrent Pilot Projects," *OpenGov Asia* (blog), January 4, 2018, https://opengovasia.com/how-the-dutch-government-is-exploring-blockchain-use-cases-through-many-concurrent-pilot-projects/.

[68] Georgia Owen, "Use of Blockchain to Be Tested by Netherlands Land Registry," *Today's Conveyancer* (blog), June 8, 2018, https://www.todaysconveyancer.co.uk/blockchain-tested-netherlands-land-registry/.

[69] G. Eder, "Digital Transformation : Blockchain and Land Titles," March 2019, https://www.semanticscholar.org/paper/Digital-Transformation-%3A-Blockchain-and-Land-Titles-Eder-Eder/db0ec8f0bcbcff014eb39b206f8e9a32bbb06a40.

[70] Mohammed Shuaib et al., "Blockchain-Based Framework for Secure and Reliable Land Registry System," *TELKOMNIKA (Telecommunication Computing Electronics and Control)* 18, no. 5 (October 1, 2020): 2560–71, https://doi.org/10.12928/telkomnika.v18i5.15787.

[71] "Ghana," *GovChain* (blog), September 5, 2019, https://govchain.world/ghana/.

[72] G. Eder, "Digital Transformation : Blockchain and Land Titles," March 2019, https://www.semanticscholar.org/paper/Digital-Transformation-%3A-Blockchain-and-Land-Titles-Eder-Eder/db0ec8f0bcbcff014eb39b206f8e9a32bbb06a40.

sanctity of the blockchain and remove the need for any retrospective changes to existing blocks, the data on the blockchain has to be the single source of truth. The need for the entity governing the recordkeeping of land titles to make sure that the land records and titles are dispute free is one of the biggest challenges to using blockchain technology for maintaining land records.[73] This is a monumental task considering the large number of pending property disputes that are currently languishing in the Indian judicial system.

b. Customary Titles

One of the assumptions made while discussing a blockchain-based system for land records is that all owners of land would have records regarding their ownership of the land. However, there are still a number of vulnerable groups such as indigenous and tribal populations with customary rights over land that may not have title documents or records to their customary lands.[74]

c. Interest without Records

Immovable property in India and other common law jurisdictions may have different types of ownership and possessory interests in the property, such as leasehold, freehold, life interest, etc. Some of these may mature into an ownership interest, while others may mature into a transfer of title to a different party.[75] Further Indian law recognises a number of forms of transferring property which does not require and often do not have any paperwork, such as succession, family partition, adverse possession, etc. It is not yet clear how these legal issues would be addressed by blockchain technology.

d. Checking of Title

The system proposed by the Centre of Excellence for Blockchain Technology stipulates that the registration department will check the ownership of the land before registering a new transfer of the property on the blockchain. However, under Indian law, it is not the duty or function of the Registrar to check the adequacy of the title of the transferor before registering a transfer of immovable property.[76] This proposal requiring the registering authority to check and (in a sense) certify the title of the transferor would imply conferring the judicial power and function of a Court on an administrative (or at best a quasi-judicial) authority to determine a purely legal issue. This is a function that the registering authority would not have the competence to determine since it may require knowledge and

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[73] Blockchain: The India Strategy, Draft Discussion Paper, Niti Aayog, January 2020, p 26 and 27

[74] Blockchain for Property: A Roll Out Map for India, India Institute, 2017 pg 60, available at http://indiai.org/blockchain-handbook/

[75] Thomas, Rod, Blockchain's Unsuitability for Real Property Transactions (January 13, 2019). Rod Thomas "Blockchain's unsuitability for real property transactions" in S Murphy and P Kenna and (eds) eConveyancing and Title Registration in Ireland (Clarus Press, Dublin, 2018), Available at SSRN: https://ssrn.com/abstract=3315000

[76] *Kusum Lata* v. *State of UP and others*, 2018 (189) AIC 953 (Alld-FB).

analysis of complex legal and jurisprudential issues. One way to address this problem may be to implement a legal system for conclusive land titling, but the scope of such a project would be much bigger than merely moving the land registration system onto a blockchain.

e. Preservation of Data
Most blockchain systems work by comparing a digitally signed hash with a digitally signed hash stored on the blockchain. Since the digitally signed versions on the blockchain cannot be reverse engineered to produce a copy of the original record, originals must always be preserved so that they can be re-hashed and digitally signed for the purposes of comparison. One small change to any of the bits of an original digital record (due to bit rot or as a result of the preservation process) or some alteration in the protocols of the recording process could make it impossible to authenticate a record at a point in the future.[77]

f. Lack of impact on corruption and double selling
Blockchain is envisioned as a mechanism to address a number of institutional limitations associated with the traditional land registration process instituted by states - most notably corruption, fraud and double selling. However, it is worth remembering that the implementation of blockchain technology (or any technology for that matter) cannot be separated from, and is directly affected by, existing institutional factors and power structures. To that end, drawing from lessons gained through the Georgian and Ghanaian experiences, we see that the introduction of blockchain into the land registration process has succumbed to those very factors that it was meant to solve; namely corruption, lack of transparency and accountability.[78] Therefore it is clear that the mere introduction of blockchain technology cannot be relied on as a silver bullet solution for the spectrum of socio-political problems that plagues the land registration process.

2.2 Education Certificates and other Document Verification

The requirement to produce original or genuine certificates is experienced by pretty much every person at various stages of life, especially during education and recruitment. Original certificates are required for admission to schools, colleges or universities, etc. and then again at the time of applying for or changing employment. The process of obtaining original certificates from various authorities usually requires physical presence,

[77] Lemieux, V. (2017). Evaluating the use of blockchain in land transactions: an archival science perspective. Eur. Proper. Law J. 6, 392–440. doi: 10.1515/eplj-2017-0019

[78] G. Eder, “Digital Transformation : Blockchain and Land Titles,” March 2019, https://www.semanticscholar.org/paper/Digital-Transformation-%3A-Blockchain-and-Land-Titles-Eder-Eder/db0ec8f0bcbcff014eb39b206f8e9a32bbb06a40.

often involving multiple visits to the authority concerned, wasting time and energy. At the other end of the spectrum, the authorities receiving the certificates such as the education authorities, employers (private or government) or even government welfare departments, etc. have to expend great efforts to verify the authenticity of the documents and ensure that fake certificates are not submitted. In this context, blockchain technology has been proposed as a means of addressing this issue.

2.2.1 Proposed systems

We will discuss below three instances where blockchain technology is being proposed as a possible solution for certificate verification: SuperCert by Niti Aayog, LegitDoc by Crossforge built for the Maharashtra State Board of Skill development, and Certificate Chain by NIC built for the Karnataka Education Board.

a. SuperCert
The Niti Aayog partnered with the Indian School of Business (ISB) and Bitgram to develop a system which would address and remove a number of the problems related to the process of accessing and verification of educational certificates. The system devised by the Niti Aayog called SuperCert has a permissioned blockchain architecture that involves decentralisation, intelligent identity encryption and identity interlinking for the issuance of educational certificates.

The system involves the creation of a student identity or "superidentity", which is a unique blockchain representation of the identity along with a set of public and private keys. Any educational certificate that is issued by the University would also contain this superidentity of the concerned student. This certificate will be converted into a hashed version of itself on the blockchain by SuperCert. Once this is done, the certification can be verified using the public key of the student and the public key of the University.[79]

This proposed system has a number of potential advantages ensuring data privacy, real-time automated verification, fraud resistance due to the immutability of the blockchain, permanence both in terms of preventing the certificates from destruction as well as ensuring that verification can still be done irrespective of changed circumstances of the issuing authority, etc. As per the Niti Aayog, the system was supposed to be deployed in pilot mode for one of the courses offered by ISB in 2020 itself.[80]

b. LegitDoc
LegitDoc is a blockchain platform created by Crossforge solutions for the Maharashtra State Board of Skill Development (MSBSD). LegitDoc makes use of the

[79] Blockchain: The India Strategy, Draft Discussion Paper, Niti Aayog, January 2020, p. 39.

[80] Blockchain: The India Strategy, Draft Discussion Paper, Niti Aayog, January 2020, p. 40.

Ethereum blockchain to secure, issue and verify the certificates issued to students by the state board for the various courses that it offers.[81]
The system consists of two key software - an issuance software and a verification software.[82]

Under the issuance procedure, LegitDoc calculates a unique hash for every student certificate pdf issued by MSBSD - which remains constant every time the hash for that pdf is calculated. This unique hash is used to verify if any changes are made to the document since any alteration to the pdf would result in a new hash being produced. Following this, the hash is stored on the blockchain and mapped to the MSBSD's digital signature. The blockchain will in turn produce the transaction data linked to this hash. The issuance software will then combine this transaction data along with the original pdf into a blockchain file that is emailed to the respective student.

The verification software works to verify the authenticity of documents uploaded by students. The verification software is hosted as a web app on the MSBSD website. Individuals looking to verify their certificates must upload the blockchain file that was sent to them by the issuance software. The verification software works by first separating the file back into a pdf and the blockchain transaction data. It then calculates the hash of the pdf and compares this hash with the hash stored on the blockchain with the help of the blockchain transaction data.

c. Certificate Chain
Certificate Chain was a system made by the National Informatics Centre (NIC) for the Karnataka Examination Authority (KEA) which conducts the Common Entrance Examination for admission to various professional colleges in the State of Karnataka and is required to verify a large number of educational certificates, caste certificates, income certificates, rural area certificates, etc. that are submitted by the candidates. The system envisages the issuers of the certificates storing the certificate details in the blockchain, in the future all certificate details that are required by a student would be stored in the blockchain as well. The system would also require some amount of metadata to be stored for the purpose of electronic data comparison. For older certificates, the NIC suggests that students upload the details of the certificate metadata which can be stored on the blockchain and the respective department systems may trigger a request to the issuing agency to notarize the certificate details.[83]

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[81] Neil Martis, "Case Study: LegitDoc Implementation by Maharashtra State Board of Skill Development(MSBSD)," *Medium* (blog), August 18, 2021, https://blog.legitdoc.com/case-study-legitdoc-implementation-by-maharashtra-state-board-of-skill-development-msbsd-72621b5a278f.

[82] Id.

[83] 'Certificate Chain', Centre of Excellence in Blockchain Technology, accessed 28 June 2022, https://blockchain.gov.in/landrecords.html.

The scope of the Certificate Chain, as envisaged by the NIC is much broader than that envisaged under SuperCert of the Niti Aayog, in that it also envisages other stakeholders joining and taking advantage of the system, such as:

- Municipalities and Revenue Departments: For the purpose of providing and verifying certificates such as birth certificates, income certificates, rural area certificates, etc. which are issued by these departments;
- Education Department: For the purpose of providing and verifying educational certificates, transfer certificates, school completion certificates, mark sheets, etc. which are issued by the department of education;
- Welfare Departments: Various departments such as tribal welfare, minority affairs, etc. which deal with welfare schemes of the government can also take advantage of this system by providing and verifying documents which would certify the beneficiaries for various welfare schemes;
- Employers: Employers (both in the public and private sector) can be onboarded to the system so that the employment history of the person can also be uploaded to the blockchain.[84]

2.2.2 International Perspectives

With the introduction of Maharashtra's blockchain-based certificate verifying system, India became the fourth country to introduce blockchain technology in the education certificate verification space - following on from Singapore, Bahrain and Malta.[85]

a. Singapore

Singapore introduced the blockchain-based OpenCerts platform in November 2017 as a means of certificate verification in the education field as part of its Smart Nation Singapore plan.[86] OpenCerts was developed through a collaboration between the Government Technology Agency, Ministry of Education, Ngee Ann Polytechnic and SkillsFuture Singapore.[87] The platform looks to issue and verify

[84] Blockchain for Government, National Informatics Centre, January, 2020, p. 46, available at https://blockchain.gov.in/Whitepaper_30jan.pdf

[85] ANI Press Release, "India Becomes the Fourth Country to Roll out Blockchain-Powered Educational Documents," *Business Standard India*, July 16, 2021, https://www.business-standard.com/content/press-releases-ani/india-becomes-the-fourth-country-to-roll-out-blockchain-powered-educational-documents-121071601003_1.html.

[86] "OpenCerts," Smart Nation Singapore, https://www.smartnation.gov.sg//initiatives/digital-government-services/opencerts

[87] Id.

tamper-proof academic certificates.[88] It makes use of the Ethereum blockchain,[89] and allows individuals to verify the status of academic certificates without the need for following up with individual universities.

b. Bahrain
Universities in Bahrain have adopted the open-source blockchain certificate verification standard known as Blockcerts.[90] Blockcerts was developed by MIT media lab and Hyland Credentials.[91] The most notable adopter of this technology was the University of Bahrain, with it being supported by the Information and eGovernment Authority in Bahrain.[92]

c. Malta
Malta became the first state to adopt blockchain-based certificate verification through its introduction of the Blockcerts platform into its higher education institutions in October 2017.[93]

2.2.3 Advantages of using blockchain

Developers and adopters have pointed to a multitude of reasons why the introduction of blockchain technology would be beneficial in the context of certificate verification. These include the following:

a. Simpler verification process and reduced incidence of falsified certificates
The use of blockchain technology can ensure that entities or institutions looking to verify documents can do so using a singular platform rather than communicating with each entity that has issued a certificate.

b. Secure and easily accessible

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[88] "OpenCerts - An Easy Way to Check and Verify Your Certificates," Singapore Government Developer Portal, March 17, 2022, https://www.developer.tech.gov.sg/products/categories/blockchain/opencerts/overview.html.

[89] "OpenCerts - Frequently Asked Questions," OpenCerts, accessed March 23, 2022, https://opencerts.io/faq.

[90] "UoB Issues Certificates Using Blockchain Technology," The Daily Tribune, accessed March 23, 2022, https://www.newsofbahrain.com/bahrain/71792.html.
"Blockcerts," Royal College of Surgeons in Ireland Medical University of Bahrain, accessed March 23, 2022, https://www.rcsi.com/bahrain/alumni/blockcerts.

[91] Blockcerts, "Blockchain Credentials," http://blockcerts.org/.

[92] Jibrel, "Bahrain Emerges as a Blockchain Leader in the Middle East," Jibrel (blog), July 15, 2019, https://medium.com/jibrel-network/bahrain-emerges-as-a-blockchain-leader-in-the-middle-east-672cc212bbf8.

[93] "Customer Story - Malta," Hyland Credentials, accessed March 23, 2022, https://www.hylandcredentials.com/customer-story-malta/.

The use of blockchain technology can ensure that only trusted parties are able to access the relevant data (certificates), and their storage on the blockchain also makes them easily accessible at all times.

2.2.4 Challenges associated with using blockchain

For all the obvious benefits associated with the use of blockchain technology in this field, it is not without its limitations and challenges. These include:

a. Distribution of Cost
The implementation of a blockchain-based platform involves heavy costs to set up as well as maintain and operate the system. Who should bear the costs for such a system in the field of education is a question that requires detailed debate and consideration.[94] If a high-cost system is set up only for public educational institutions then the costs may be borne by the government, however in the fragmented field of education in India with both private and public institutions involved, the question merits a much deeper discussion since private institutions are likely to pass the cost on to students.

b. Standardisation
In the case of sectors run through strong centralised regulators such as banking, insurance, financial investment, etc. standardisation bodies such as the central regulators may be able to create and specify technology standards ensuring that only those organisations which meet the stringent criteria are able to operate within the network. However, the education sector does not have a central regulatory body spanning the entire lifespan of the educational journey of a student.[95] Even within the same tier of the educational journey, certificates are issued by different organisations, for eg. Class X and Class XII Board certificates may be issued by the CBSE (Central Board for Secondary Education), the ICSE/ISCE (Indian Certificate for Secondary Education/Indian School Certificate Examination), as well as individual State Education Boards. Setting up an independent body to prescribe and enforce standardisation across institutions spanning the different tiers of the educational journey would be an additional challenge in implementing a blockchain system on a national scale.

c. Interoperability
Interoperability of a new blockchain-based system with the legacy systems of various educational systems would be a big issue in the fragmented and partly privatised education sector in India. In today's globalised economy with the freedom of labour and the free flow of students to pursue academic opportunities across borders, setting up a global blockchain network to enable the smooth

[94] Delgado-von-Eitzen, C.; Anido-Rifón, L.; Fernández-Iglesias, M.J. Blockchain Applications in Education: A Systematic Literature Review. Appl. Sci. 2021, 11, 11811. https://doi.org/10.3390/app112411811

[95] Grech, A. and Camilleri, A. F. (2017) Blockchain in Education. Inamorato dos Santos, A. (ed.) EUR 28778 EN; doi:10.2760/60649

transition of students to and from different countries would require a monumental effort to address the interoperability issues.[96] At a global level solving the regulatory and legal problems, especially those regarding privacy would become an even more complicated exercise.[97]

d. Trust issues
In a blockchain-based certificate verification system, it is likely that the educational institutions would be the ones making and verifying the transactions. But researchers have also posed questions on the trustworthiness of these institutions themselves.[98] Trustworthiness of educational institutes becomes an even bigger issue in developing countries such as India where ensuring the quality of educational institutions is a big challenge.[99]

2.3 Pharmaceutical Supply Chain Management

India has the third largest pharmaceutical industry in the world in terms of volume which accounts for about 10% of the world's production, unfortunately, according to some estimates it also produces 35% of the world's fake drugs.[100] The Niti Aayog through its research and interviews found that drugs coming directly from manufacturers are trustworthy but the risk of fake drugs entering the system increases when products are passed on between different stages of the complex supply chain i.e. wholesalers, distributors, retailers, etc. Thus there is a risk of drugs being replaced, adulterated or stolen at each of these transfer points.[101]

2.3.1 Proposed Use Cases

Amidst these fears of pharmaceutical fraud, blockchain has been suggested as a tool to address these concerns. At present, in India, there are two examples of the deployment of blockchain technology in pharmaceutical supply chain management that are in various stages of readiness, (i) the Niti Aayog Pilot project, and (ii) the Drugs Logistics system by NIC for the Government of Karnataka.

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[96] Delgado-von-Eitzen, C.; Anido-Rifón, L.; Fernández-Iglesias, M.J. Blockchain Applications in Education: A Systematic Literature Review. Appl. Sci. 2021, 11, 11811. https://doi.org/10.3390/app112411811

[97] Steiu, M.-F. (2020). Blockchain in education: Opportunities, applications, and challenges. First Monday, 25(9). https://doi.org/10.5210/fm.v25i9.10654

[98] Audrey Watters, The Blockchain for Education: An Introduction, http://hackeducation.com/2016/04/07/blockchain-education-guide

[99] Jewl Hoque, Quality Concern in Higher Education in India, EDULIGHT Journal, Volume 7, Issue 13, May, 2018.

[100] Debapriya Nandan, "How blockchain can help fight counterfeit drugs in India", Forbes India, available at https://www.forbesindia.com/blog/technology/how-blockchain-can-help-fight-counterfeit-drugs-in-india.

[101] Blockchain: The India Strategy, Draft Discussion Paper, Niti Aayog, January 2020, p. 35.

a. Niti Aayog Pilot

The Niti Aayog organised a pilot project to deploy blockchain technology in the healthcare and technology domain which involved a large number of stakeholders including drug manufacturers, transporters, logistics providers, retailers, etc. The project integrated a number of independent IT systems from the various stakeholders for the transmission of information on the receipt and transfer of goods with a concerted effort made to ensure that manual entry of information was restricted.

The system envisaged that as the goods moved through the supply chain, each transaction was transmitted through internal systems in an automated manner and registered as well as time-stamped using a decentralised ledger. Manufacturing inputs such as active ingredients and excipients were tracked and linked to the final product. The blockchain also captured and showed critical details such as the location and temperature of the goods through IoT devices attached to the packages making the journey of the goods visible to all stakeholders and limiting the possibility of record tampering.

This system allowed manufacturers and other stakeholders in the supply chain to gain real-time access and greater visibility throughout the supply chain from the stage of manufacturing right up to the point of sale at the pharmacies. This increased transparency would enable the stakeholders to identify the last stakeholder to have handled the goods in case any problems arise in the course of the supply chain. Further, even the consumers would have the ability to verify the authenticity of the drugs that they are purchasing.[102]

b. NIC Drug Logistics System

NIC has proposed a medical supply chain management system based on blockchain technology for the government of Karnataka which procures and supplies free drugs with the help of NRHM for patients across the state. The government of Karnataka currently uses an online supply chain management software to automate the supply chain, call Aushudha. This system collects the annual requirements from almost 3000 hospitals and submits a consolidated requirement to the State Therapeutic Committee. Purchase Orders are sent to the suppliers with the delivery schedule, who then send the drugs to the warehouses where these drugs are inspected for quality control. Thereafter monthly requirements of the hospitals are sent to the warehouses which approve the requirements and send the drugs to the hospitals.

The NICs system proposes to integrate the existing Aushudha software to record transactions in a blockchain-based ledger at each stage of the supply chain thereby providing improved transparency and traceability across the system. The

[102] Blockchain: The India Strategy, Draft Discussion Paper, Niti Aayog, January 2020, p 36 and 37.

main transactions that are proposed to be recorded in the blockchain are given below:

a. Procurement and Schedule
   Purchase Order for every supplier containing drug-wise and warehouse-wise quantities along with the time schedule. The details of Notification of Award [NOA] number, po number, supplier, drug name, po date, rate, warehouse, and quantity are proposed to be stored in the blockchain.

b. Warehouse Inward
   The warehouse receives the drugs against each purchase order along with batch details and physically verifies the same. The pre-conditions before receiving the drugs can be ascertained by requesting the details from the blockchain. The details of PO Number, Supplier, Drug Name, Warehouse, Receipt Date, Invoice No., Invoice Date, Rate, Batch No., Mfg. Date, Exp. Date, Batch Qty are stored in the blockchain. Payment to the supplier can also be Initiated at this stage itself using the smart contract code registered in the blockchain.

c. Quality Check
   The quality check is done for every batch of drugs by selecting the samples from randomly selected warehouses. The warehouses shall send the drugs to the QC Section which will test the drugs and issue QC Code. If any of the drugs is identified as "Not of Standard Quality", the batch is frozen across the warehouses and the Hospitals so that the further issuance is stopped. Drug Name, Batch No., Warehouse, Qty Lifted, QC Code are stored in the blockchain.

d. Monthly Indent by Hospitals
   Since the hospital to warehouse mapping is already done during master data creation, the monthly indent is raised by the hospital to the mapped warehouse only. The warehouse will approve the indent with or without change in the quantity based on the stock available. The drugs approved by the warehouse are transported to the hospitals. Indent No., Warehouse, Institute, Batch No., Mfg Date, Exp Date, Quantity, Supplier, Rate, Drug, Outward No., Outward Date will be stored in the Blockchain.

e. Receipt and Issue by Hospitals
   Hospital receives the drugs and its main store will issue the drugs to the sub store on daily/weekly basis. Inward No., Inward Date, Warehouse Outward No., Institute, Warehouse, Indent No., Drug, Batch No., Mfg Date,

Exp Date, Rate, Qty, Outward No., Supplier will be stored in the Blockchain so that the authentic batches only are received by the Hospitals.[103]

2.3.2 International Perspectives

Having identified how such a system could operate within India, it is imperative that we analyse its implementation in other jurisdictions.

a. United States

The Food and drug administration of the United States adopted a pilot programme under the Drug Supply Chain Security Act, wherein private entities were invited to propose novel technological systems that would help secure the pharmaceutical supply chain.[104] The DSCA outlines a number of requirements that the various players within the pharmaceutical supply chain must comply with in relation to "*achieve[ing] interoperable, electronic tracing of products at the package level to identify and trace certain prescription drugs as they are distributed in the United States.*"[105]

One of the proposed systems involved the use of blockchain technology to facilitate the traceability of prescription drugs and vaccines.[106] The program was initiated in collaboration with IBM, KPMG, Merck and Walmart.[107] The blockchain system was connected with Merck's existing standard system for serialisation, in order to ensure its interoperability.[108] The system allows for medicines to be easily traced across the various actors involved in the supply chain, which is vital for the government in instances such as when a drug is recalled. Previously it could take up to 3 days to inform all parties involved in pharmaceutical manufacturing and distribution about the compromised nature of a batch of drugs; however, estimates

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[103] Blockchain for Government, National Informatics Centre, January, 2020, p. 43,44, available at https://blockchain.gov.in/Whitepaper_30jan.pdf

[104] Office of the Commissioner, "FDA Takes New Steps to Adopt More Modern Technologies for Improving the Security of the Drug Supply Chain through Innovations That Improve Tracking and Tracing of Medicines," FDA (FDA, March 24, 2020), https://www.fda.gov/news-events/press-announcements/fda-takes-new-steps-adopt-more-modern-technologies-improving-security-drug-supply-chain-through.

[105] "Drug Supply Chain Security Act (DSCSA)," FDA (FDA, March 9, 2022), https://www.fda.gov/drugs/drug-supply-chain-integrity/drug-supply-chain-security-act-dscsa.

[106] Office of the Commissioner, "FDA Takes New Steps to Adopt More Modern Technologies for Improving the Security of the Drug Supply Chain through Innovations That Improve Tracking and Tracing of Medicines," FDA (FDA, March 24, 2020), https://www.fda.gov/news-events/press-announcements/fda-takes-new-steps-adopt-more-modern-technologies-improving-security-drug-supply-chain-through.

[107] Id.

[108] Id.

from the pilot program show that this can be brought down to a matter of seconds with the use of blockchain technology.[109]

2.3.3 Challenges and Drawbacks

Based on the systems currently being implemented, it is clear that blockchain technology does have a potentially significant role to play in securing the pharmaceutical supply chain in India and globally.

a. High Cost of Implementation
The high costs of implementation of blockchain-based platforms may get exacerbated when applied in the pharmaceutical supply chain. This is because tracking various drugs across the complicated supply chain may require the installation of a number of sensors and the upgrading of technologies. Maintenance of such a large number of IoT devices and ensuring their accuracy would involve a significant cost.[110]

b. Additional Processes
In order for the blockchain-based system to effectively track an item in the supply chain, changes may need to be made in the traditional processes which may require additional actions and effort on the part of stakeholders, for eg. the NITI Aayog pilot for tracking pharmaceuticals requires drug packaging to have a three-tiered QR Code or barcode to enable tracking through the supply chain. This is not a legal requirement for the domestic drug industry in India. Thus stakeholders were required to manually stick barcode stickers and scan the same at each stage of transfer. Such additional efforts may cause reluctance on the part of the stakeholders, which will need to be properly addressed.[111]

2.4 Common Challenges across all three use cases

While blockchain technology has a number of advantages and many use cases, one must not lose sight of the limitations of this technology, a theme which appears to be explored much less compared to the advantages and potential use cases of the technology. Keeping this in mind we now look at some of the limitations associated with blockchain that would be applicable across all three mentioned use cases.

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[109] Mark Treshock, "How the FDA Is Piloting Blockchain for the Pharmaceutical Supply Chain," IBM Supply Chain and Blockchain Blog (blog), May 4, 2020, https://www.ibm.com/blogs/blockchain/2020/05/how-the-fda-is-piloting-blockchain-for-the-pharmaceutical-supply-chain/.

[110] D. Jaisimha and P. Kumar, "Deployment of Smart Contract based Blockchain to Optimise Pharma Supply Chain", IJRESM, vol. 5, no. 1, pp 67-73, Jan. 2022.

[111] Blockchain: The India Strategy, Draft Discussion Paper, Niti Aayog, January 2020, pg 27.

a. Scalability

Blockchain is a peer-to-peer system that allows everyone to add new transaction data to the collectively maintained history and also ensures that the history of the transactions is protected from being manipulated or forged. These functions are performed by making use of an immutable append-only data structure which requires the solution of a hash puzzle whenever a new block is added, which is a time-consuming process. This insistence on solving a cryptographic puzzle adds a very useful security factor to the data, however, the trade-off is that it reduces processing speed as the network becomes bigger.[112] These issues may be addressed to an extent through technological means such as changing the architecture of the distributed ledger technology, conducting transactions off-chain, permissioned networks, etc.[113] Scalability of Blockchain systems is affected by various factors such as architecture, the configuration of the Blockchain platform, variable requirements for processing power, network bandwidth, block size, consensus, transaction validation mechanisms, privacy requirements, file system, data storage, etc. all of which need to be taken into account while designing the architecture of any blockchain system.[114]

b. High Implementation and Maintenance Costs

Implementing a blockchain platform for any process involves high costs including development costs, hiring of professionals for the development and maintenance of the platform, training existing users on the system, etc.[115] If the use case requires additional IoT devices then the cost of implementation increases to an even greater extent. Further Proof of Work type of blockchains also require a large amount of computational power, which itself is an expensive proposition and leads to high energy consumption.[116]

c. Lack of Flexibility

Since blockchain is a complicated technical construct that uses a variety of concepts and protocols which are optimized and adapted to one another, changing such a fine-tuned system can be a very challenging proposition. There is no established protocol regarding how to change the major components of a blockchain once it has started operations. The immutability of the data also makes it difficult to fix bugs or make adjustments to the protocol, which makes blockchain

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[112] Daniel Drescher, “Blockchain Basics: A Non-Technical Introduction in 25 Steps”, Frankfurt am Main, Germany, Apress, Chapter 22.

[113] Gwyneth Iredale, Top Disadvantages of Blockchain Technology, https://101blockchains.com/disadvantages-of-blockchain/, accessed on January 18, 2022.

[114] National Strategy on Blockchain, Government of India, Ministry of Electronics and Information Technology, January, 2021, pg 16.

[115] Gwyneth Iredale, Top Disadvantages of Blockchain Technology, https://101blockchains.com/disadvantages-of-blockchain/, accessed on January 18, 2022.

[116] Strebko, Julija & Romanovs, Andrejs. (2018). The Advantages and Disadvantages of the Blockchain Technology. 1-6. 10.1109/AIEEE.2018.8592253.

a less flexible technology than others.[117] Blockchain technology is still at a fairly nascent stage and there are various people trying to solve various issues and add functionalities, which may lead to hesitation from entities in adopting it as they would prefer to wait for the technology to mature.[118]

d. Interoperability with Legacy systems

Integration of blockchain technology with existing and usually complex legacy systems is one of the real challenges for large scale adoption of this technology. This is one of the reasons why adoption of blockchain technology has so far been limited to specific parts of businesses, as corporations figure out their blockchain strategy. Even use cases based on public blockchain have faced challenges in integrating information received from external systems in a trusted manner. Given the predominance of such legacy systems (such as national IDs, payment systems, supply chain information, weather etc.) in the current economy, it is imperative for blockchain systems and platforms to develop the capability to integrate with legacy systems across the board.[119] Even within the blockchain space, there are multiple kinds of blockchain networks which work differently, trying to solve various issues and functionalities in their own unique way. This leads to interoperability issues where these chains themselves are also not able to communicate effectively.[120]

e. Data Immutability and Human error

Blockchain's '*immutable*' nature means that data are once written cannot be removed, thus if there is a mistake in the data that is entered on the blockchain platform then it cannot be removed, deleted or changed. While this may have been a laudable functionality of the blockchain when designed as a network to enable the transfer of value, this may lead to problems of privacy, mischief and human error in a real-world enterprise scenario. The problem of wrong counterparties or incorrect entries would get even more amplified if these mistakes cannot be removed from the network.[121]

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[117] Daniel Drescher, "Blockchain Basics: A Non-Technical Introduction in 25 Steps", Frankfurt am Main, Germany, Apress, Chapter 22.

[118] Gwyneth Iredale, Top Disadvantages of Blockchain Technology, https://101blockchains.com/disadvantages-of-blockchain/, accessed on January 18, 2022.

[119] Blockchain: The India Strategy, Draft Discussion Paper, Niti Aayog, January 2020, pg. 27.

[120] Gwyneth Iredale, Top Disadvantages of Blockchain Technology, https://101blockchains.com/disadvantages-of-blockchain/, accessed on January 18, 2022.

[121] Richard Lumb, David treat, Owen Jelf, EDITING THE UNEDITABLE BLOCKCHAIN: Why distributed ledger technology must adapt to an imperfect world, https://bravenewcoin.com/insights/editing-the-uneditable-blockchain--why-distributed-ledger-technology-must-adapt-to-an-imperfect-world, accessed on January 19, 2022.

Conclusion

Blockchain is considered by many as a potentially transformative force in multiple aspects of government and private sector operations. The government of India appears to have also recognised the potential of this technology and tried to roll out various governance solutions based on this technology. However, while blockchain technology has the potential to solve a number of issues in various sectors, it is not without its own challenges. Further, a number of advantages which these solutions claim to provide can also be achieved through other technologies including distributed databases or central databases with distributed API.[122] It must be pointed out that in a situation where both blockchain and a database can be deployed, a database would be preferable since it provides better performance in terms of throughput and latency.[123]

That said, it also beckons mentioning that some of the challenges mentioned above such as interoperability, slower throughput, etc. may be mitigated through technological solutions or "fixes". In view of such countervailing propositions it is absolutely imperative that there is put into place a transparent process to assess whether blockchain is the correct solution for a given situation. This would ensure that investments are not made unwisely into projects where blockchain may be an unviable solution, thus avoiding disillusionment and buyer fatigue.

[122] Blockchain: The India Strategy, Draft Discussion Paper, Niti Aayog, January 2020, pg 17.

[123] K. Wüst and A. Gervais, "Do you Need a Blockchain?," *2018 Crypto Valley Conference on Blockchain Technology (CVCBT)*, 2018, pp. 45-54, doi: 10.1109/CVCBT.2018.00011.