BRANZ

External Reasearch Report

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Applying Blockchain to product compliance and assurance in the construction industry

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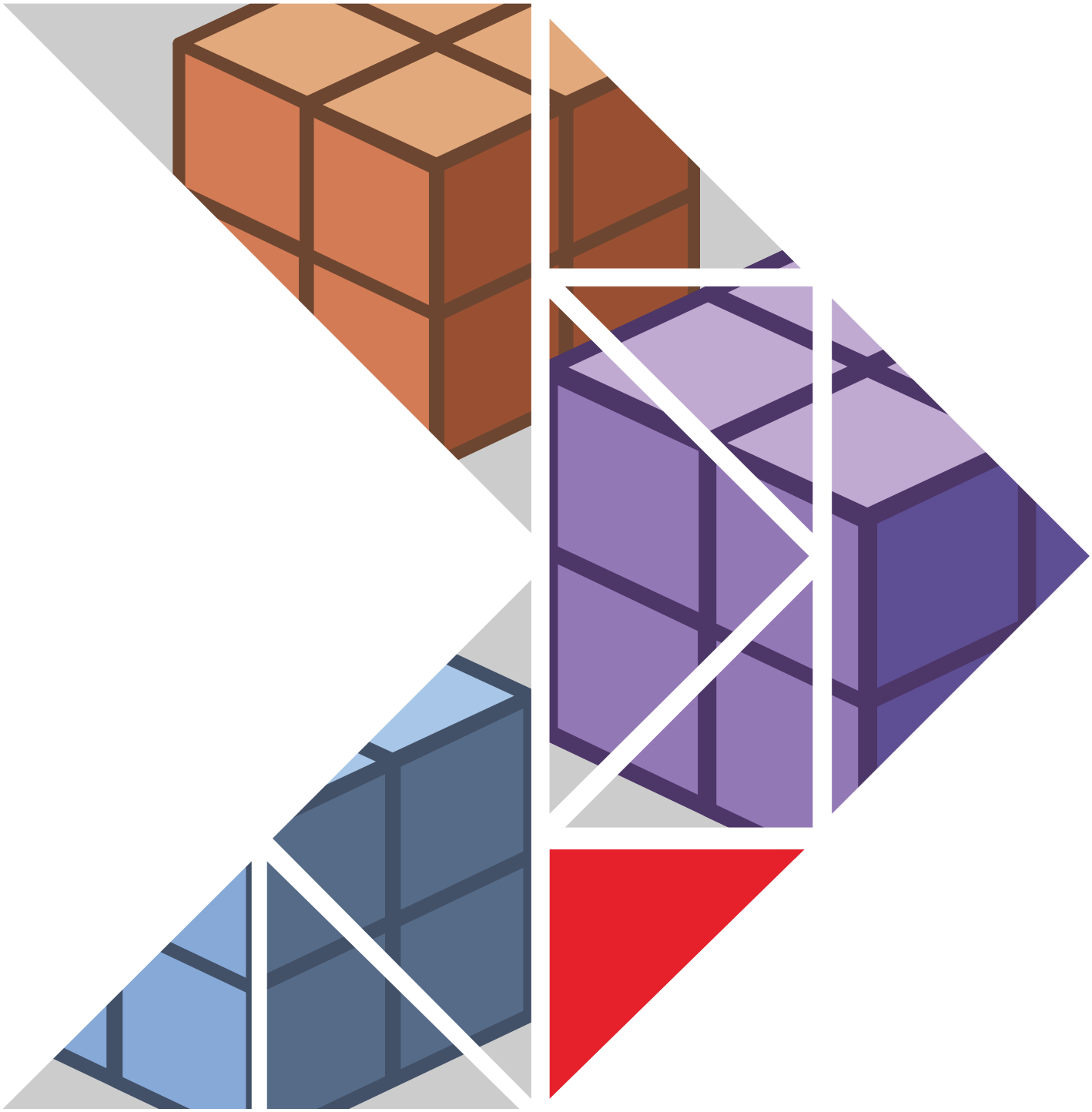

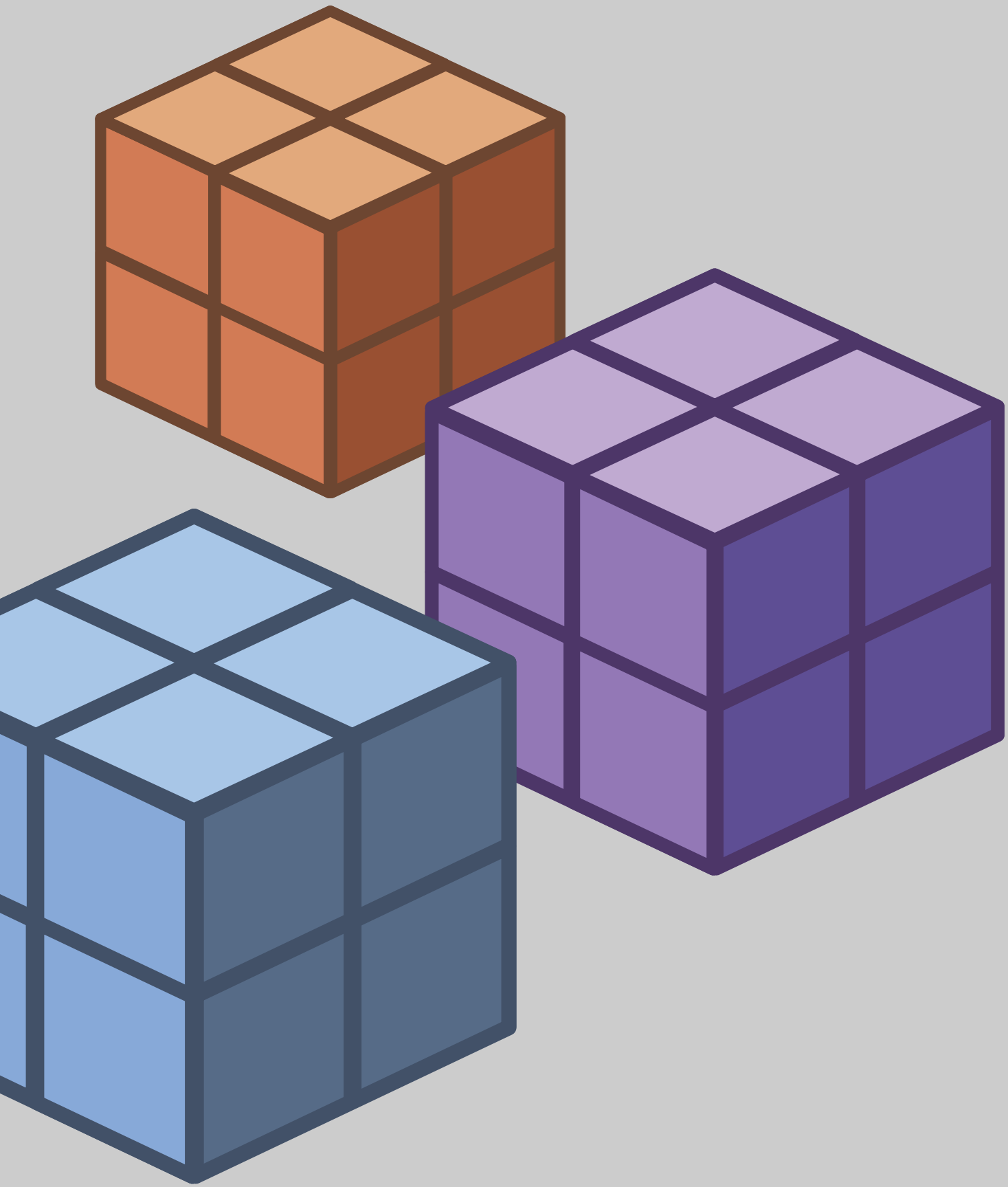

About BRANZ

BRANZ undertakes and invests in research by BRANZ science teams and external research agencies to unlock new knowledge, addressing current and emerging challenges of New Zealand's built environment. The 2018 BRANZ Inc. Building Research Levy Prospectus sought research to understand the potential application of Blockchain technology to compliance and assurance in the building industry. This research report undertaken by GS1 New Zealand aims to help us to begin to understand where and how Blockchain technology could provide new solutions and approaches to product compliance and assurance.

About GS1 New Zealand

GS1 is a global family of not-for-profit, locally owned organisations that provide help for organisations to trade and exchange information. While we are best known for barcode technology, GS1 are global experts in supply chain data exchange of many kinds.
Here in New Zealand, GS1 NZ is owned by more than 8,000 members, spanning most industry sectors including food and grocery, healthcare, construction, agribusiness and government.
A volunteer board governs GS1 NZ and is made up of representatives from the healthcare, government, food and grocery, and primary industry sectors. In New Zealand, the Building Industry Federation appoints an industry representative to our board.
In September 2017 GS1 announced a collaboration with IBM and Microsoft to leverage GS1 Standards in their enterprise blockchain applications for supply chain clients. GS1's global standards for identification and structured data enable blockchain network users to scale enterprise adoption and maintain a single, shared version of the truth about supply chain and logistics events-increasing data integrity and trust between parties and reducing data duplication and reconciliation.

Disclaimer

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1 Glossary of terms

Term	Definition
Accreditation assessments	Accreditation assessments are assessments of an accredited organisation or Building Consent Authority's compliance with the accreditation requirements in the Building (Accreditation of Building Consent Authorities) Regulations 2006.
Accreditation body	An accreditation body is an organisation that provides an accreditation service, which is the formal, third party recognition of competence to perform specific tasks. In regard to the construction sector in New Zealand, the accreditation body is appointed by the Chief Executive of the Ministry of Business, Innovation and Employment to undertake accreditation assessments. The current accreditation body is International Accreditation New Zealand.
BIM	Building information modelling.
Bitcoin	Bitcoin is a well-known cryptocurrency, based on the proof-of-work Blockchain.
Blockchain	Blockchain is a type of distributed ledger technology that is comprised of unchangeable, digitally recorded data packages called blocks, where each block is then 'chained' to the next block, using a cryptographic signature.
Block	A block is an unchangeable, digitally recorded data package. Transactions from the network fill blocks and, as the transactions are validated, they are compiled into the Blockchain permanently. Blocks include a timestamp and are built in such a way that they cannot be changed once recorded.
BRANZ	BRANZ stands for Building Research Association of New Zealand. BRANZ is an independent research organisation providing impartial evidence-based advice on critical issues in building and construction in New Zealand, to industry and government.
Building Code	The Building Code is contained in regulations under the Building Act 2004. The Building Act 2004 and associated regulations govern the building sector and also set out the rules for the construction, alteration, demolition, and maintenance of new and existing buildings in New Zealand.
Building Consent Authority (BCA)	A Building Consent Authority (BCA) can exercise powers under the Building Act 2004 related to the performance of building control functions. An organisation or person must be accredited and registered to be a Building Consent Authority.
Code Compliance Certificate	Code Compliance Certificates are issued by a Building Consent Authority confirming that certain building works have been completed and comply with the building consent.
Cryptocurrency	Cryptocurrency is a digital store of monetary value, such as Bitcoin or Litecoin, the primary use of which is to buy and sell goods, services, or property. Cryptocurrencies are cryptographically secured against counterfeit and often are not issued or controlled by any centralised authority. Cryptocurrencies can be referred to as tokens or coins.
DApps	DApps are decentralised applications, or applications that exist on a decentralised network. They often use smart contracts in their back-end code and are common in the Ethereum network.
Distributed ledger	A distributed ledger is a type of database that is spread across multiple sites, countries, or institutions. Records are stored one after the other in a continuous ledger. Distributed ledger data can be either permissioned or unpermissioned to control who can view it.
DLT	Distributed Ledger Technologies are a type of database, or system of records, that is shared, replicated, and synchronised among the members of a network.
Ethereum	Ethereum is an open software platform based on Blockchain technology that enables developers to write smart contracts and build and deploy decentralised applications.
Fork	A fork alters the Blockchain data in a public Blockchain.
Global Location Number (GLN)	A GLN is a unique identifier that can be used by companies to identify a corporate entity or a physical location. It can be encoded into a barcode.

Term	Definition
Global Trade Item Number (GTIN)	GTIN describes a family of GS1 global data structures that can be encoded into various types of data carriers such as barcodes and RFID tags. GTIN is the foundation of the GS1 system and is used to uniquely identify trade items (products and services) sold, delivered, warehoused, and invoiced throughout the supply chain.
GS1 New Zealand	This is New Zealand's member organisation of GS1, the global, not-for-profit, supply chain standards development organisation based in Belgium. Established in 1979, the organisation assists businesses with supply chain management initiatives based on GS1 global supply chain standards and solutions, including barcode and numbering standards and services. GS1 New Zealand is a membership-based organisation and an incorporated society under the Incorporated Societies Act 1908.
Hyperledger	Started by the Linux Foundation, Hyperledger is an umbrella project of open source Blockchains.
IANZ	International Accreditation New Zealand.
Immutable	This is 'unable to be changed' data stored in a Blockchain and cannot be changed (not even by administrators).
ISO	International Organisation for Standardisation.
Licensed Building Practitioner	This is a building practitioner whose name has been entered onto the Ministry of Business, Innovation and Employment's register of licensed building practitioners, and who is permitted, within his or her licence class, to design, construct, or supervise restricted building work.
MBIE	The Ministry of Business, Innovation and Employment (MBIE) is the over-arching regulator of New Zealand's building system. Its role is to work with stakeholders to deliver fit-for-purpose, performance-based, building regulation that protects the public's safety and property and helps lift the sector's performance.
Mining	Mining is a process by which transactions are verified and added to a Blockchain. This process of solving cryptographic problems using computing hardware also triggers the release of cryptocurrencies.
Node	A node is any computer that connects to the Blockchain network.
Non-Compliant Product	This is a building product used in situations where it does not comply with the requirements of the New Zealand Building Code and relevant standards. A building product can be both non-compliant and non-conforming.
Non-Conforming Product (NCP)	These building products and materials claim to be something they are not, do not meet required standards for their intended use, or are marketed or supplied with the intent to deceive those who use them.
Permissioned ledger	A permissioned ledger is a ledger where actors (government departments or banks, for example) must have permission to access the ledger. Permissioned ledgers may have one or many owners. When a new record is added, the ledger's integrity is checked by a limited consensus process. This is carried out by trusted actors,which makes maintaining a shared record much simpler than the consensus process used by unpermissioned ledgers.
Product substitution	This can occur when a manufacturer, importer or supplier submits their product for third party certification testing and, after the certification is granted, alters it without retesting or recertifying the product. It can also occur when a seemingly identical (and potentially non-confirming) replacement building product is offered on a construction site or elsewhere.
Product Technical Statement (PTS)	MBIE encourages the use of a PTS as a way for manufacturers and importers to summarise key information, technical evidence, and relevant compliance pathways for building products.
Provenance	Place of origin.
RFID	RFID is an acronym for "radio-frequency identification" and refers to a technology whereby digital data is encoded on RFID tags or smart labels and are captured by a reader via radio waves.
Smart contract	Smart contracts contain terms recorded in a computer language instead of legal language. Smart contracts can be automatically executed by a computing system, such as a suitable distributed ledger system.
TLA	Territorial Local Authority.
Unpermissioned ledger	Unpermissioned ledgers such as Bitcoin have no single owner — indeed, they cannot be owned. The purpose of an unpermissioned ledger is to allow anyone to contribute data to the ledger and for everyone in possession of the ledger to have identical copies.

2 Executive summary

Blockchain overview – why the hype?

Blockchain is a relatively new technology that has attracted a lot of attention and investment over recent years.[1] Blockchain is a decentralised, distributed record, or 'ledger', of transactions that are stored in a permanent and nearly-inalterable way using cryptographic techniques. Everyone has a copy of the ledger. While closely associated with Bitcoin, blockchain is not Bitcoin, rather it is the underlying technology that enables Bitcoin transactions.

This overarching technology includes several supporting technologies built around the distributed, shared ledger of transactions. Algorithms, or some other method determined by the Blockchain network, facilitate decentralised consensus, are used to validate a transaction, and may be written to a public ledger.

There is a lot of optimism about Blockchain's potential application in solving many real-world problems. The excitement around Blockchain has generated a renewed interest enabling enhanced data sharing, without the need for central authority to govern how this is done. Improving the flow of products and enabling more sustainable and transparent supply chains are goals for many organisations today, where blockchain might help. In New Zealand, the construction industry has a critical need to ensure that the products that flow through their supply chains are fit for purpose and adhere to regulations.

1 In this report we use the term Blockchain to refer to distributed ledger technologies (DLT).

Blockchain is only part of a technological solution

It is important to understand that Blockchain technology alone does not solve the technology business challenges that industries are facing today. A 'multi-layer' ecosystem is necessary. Business applications, such as traceability systems or order to cash systems, are still required to capture and share information about events within the supply chain and are one layer of a 'data sharing' network. Blockchain can be considered another layer of that network. It adds some very specific qualities to the transactions typically generated by business applications, which are then written to a Blockchain, including immutability of information, recording of events and time-ordering of transactions.

Technology alternatives – blockchain will need to compete with others

Other technologies exist today that share information across supply chains, capture events and can include security features that make it difficult to tamper with data. Blockchain will need to compete with technologies already in use for coordinating supply chain transactions. To successfully compete, Blockchain will need to offer greater benefits to users than many of the legacy systems that operate today. To compete with other technologies, Blockchain advocates also see other hurdles to overcome that are already addressed by some existing technologies.

Technology maturity – Blockchain needs to scale better to compete

The hype around Blockchain has led to many pilot studies being initiated in the global supply chain space. However, most appear to have not moved beyond the pilot phase. Blockchain has multiple technical challenges to overcome in realising its full potential. These challenges include scalability of transactions and interoperability between systems. According to a recent survey, 40% of executives see scalability in Blockchain technologies as a major issue for enterprise implementation (GS1, 2018).

Scalability concerns must be effectively addressed before Blockchain can be adopted more widely outside of cryptocurrency transactions that exchange very limited amounts of information. Product assurance information can be extensive and unlikely to be hosted per se on a Blockchain without encountering scalability issues. Rather, the information is likely to held 'off-chain' and referenced by Blockchain transactions.

The interoperability hurdle – standards work underway

Blockchain advocates will need to agree on standards and common protocols generally and to support any industry ecosystem or network. Otherwise, siloed Blockchains will enable proprietary offerings that do not interoperate with each other thereby offering limited benefit to supply chain participants. Many construction products are imported into New Zealand and often certified or tested in overseas

market places. Blockchains will need to be able to seamlessly exchange product assurance information not only within the New Zealand construction sector but also globally.

The World Trade Organisation report into Blockchain states that:

> “ The technology is still maturing, and many challenges, including technical, interoperability and legal issues, need to be addressed before the technology can be used to its full potential. In particular, technical solutions need to be developed to address the ‘digital island problem’ and ensure that Blockchains can speak to each other, and rules need to be drafted to clarify applicable laws and regulate responsibilities. Without this regulatory layer, Blockchain will likely be confined to proofs of concept and pilot projects (Ganne, 2018, p.112).”

Ultimately, the report argues that distributed ledgers will complement existing systems rather than replacing them (Ibid). Interoperability is essential for success across today’s just-in-time global supply chain networks, and for Blockchain to reach its potential. The process is currently underway to create a suite of Blockchain Standards. Australia is managing the Secretariat of the International Technical Committee for Blockchain Standards (ISO/TC 307), and New Zealand is being represented in this project.

Technology adoption hurdles – coordination and governance

Assuming the technical and standards issues are settled, like other technologies Blockchain will need to overcome technology adoption hurdles. One of the promising features of Blockchain is that it can enhance supply chain coordination. But paradoxically, to do so, blockchain requires coordinated adoption by participants operating in complex supply chain ‘mazes’. In the case of widely adopted GS1 data standards (e.g. product identifiers), this collective action problem was overcome by government and large retailers and suppliers collaborating to introduce these supply networks.

The adoption path for Blockchain is not clear at present, at least for a fully decentralised Blockchain solution. The focus for the technology today is ‘permission-based’ Blockchain, rather than the pure fully-decentralised Blockchain. In a permission-based model, parties afford some degree of trust to a central authority, permitting selection of consensus mechanisms that are more efficient for trade.

The Blockchain model appropriate for the construction sector is most likely to be a consortium-based model. This would involve necessary leadership and collaboration between large industry players, most probably from demand side stakeholders – e.g. retailers/ merchants. Blockchain participation would involve pre-approved nodes on the network. We are not aware any such initiative.

Another adoption hurdle - the need for supportive regulatory settings

This is an issue that affects all forms of technology adoption used for sharing data, not just blockchain. Regulatory settings that make clear expectations around basic product information disclosure, provide an environment in which technology solutions can compete to meet these needs.

We interviewed a wide range of industry stakeholders, including procurement specialists, retail executives, regulators and builders. We found that:

- technical information about similar building products varies considerably; there is lack of consistent information about a product's technical specifications, certifications, warranties and limitations.
- information is often sourced from supplier websites that may or may not be up-to-date or where product assurance data is either difficult to find or missing.
- digital representations of products on websites and product data bases are not using standardised identifiers (even for the same product) universally making it difficult to accurately match a physical product its 'digital twin', especially in an on-line environment.
- systems are not in place to accurately identify non-compliant building products.

This uncertainty may place limits on the pace of innovation and sector productivity. We talked to major industry participants who no longer import new products due to this uncertainty and the financial risks associated with new product failures.

The first step required is to accelerate technology adoption for information sharing between trading partners in the construction sector and for government and industry to set minimum product identification standards and requirements for accurate product assurance information disclosure. This would support enhanced interoperability and data exchange outcomes and the availability of accurate product assurance information.

Assess your business need first – and look at alternative technology solution options

When industry discusses the concept of 'enterprise Blockchains', in many cases the conversation is about how we all collaborate to make supply chains more transparent and safer. Regulatory requirements, product identification requirements, data carriers and data capture requirements and data sharing requirements, are prerequisites for any Blockchain ledger which simply serves as an immutable audit trail of transactions.

The underlying technology – the concept of 'shared ledgers' of data – needs to address a significantly different set of requirements when applied to supply chains and the business challenges facing those supply chains. Before a distributed ledger of transactions can become relevant, there needs to be some analysis of the business process opportunity, the data capture requirements and the data sharing requirements.

Once Blockchain has reached an appropriate level of development and implementation, businesses will be better able to weigh the pros and cons of investment in Blockchain relative to other technologies. The pros and cons will depend heavily on the intended use case.

Conclusions

Blockchain is and remains an interesting technology that should be followed closely by the industry. There are currently many pilot studies underway in many sectors. Some may succeed, and many will fail given the practical experience and hurdles we have identified. These pilots will bring about learnings and help evolve the technology. Blockchain will mature, standards will be created and a niche for where Blockchain is the appropriate solution will be found. While it is too early to tell what that niche will be, the construction sector should follow the development of Blockchain closely for any potential efficacy.

While there is potential for Blockchain technology to be applied to product assurance and compliance in the construction industry, the technology is not yet well enough developed. To facilitate Blockchain adoption, or indeed strengthen adoption of existing information sharing technologies, a pre-requisite is to clarify regulatory expectations on product assurance information disclosures.

Until Blockchain proves to be successfully scalable, and interoperability is enabled, existing technologies can address this information sharing need. A repository of standardised building product assurance information could be created and made widely available, as in other countries. Technology is not the constraint to providing easy access to product assurance information, nor is Blockchain necessarily a preferred future solution. Rather a key constraint is a lack of minimum product identification standards and requirements for accurate product assurance information disclosure. This would support enhanced interoperability and data exchange outcomes, regardless of the choice of technology solution.

3 Introduction

Throughout much of human history, technological advances have driven the direction and scope of industry. One of the newest technological advances is Blockchain. It has attracted a lot of attention globally in the last few years and is seen by some as the next big technological 'game changer'.

To date, much of the excitement about Blockchain is about the possibility of seamlessly sharing data across the supply chain or ecosystem in question.

This research report focuses on understanding the hype around Blockchain and its potential use for product assurance and compliance in the New Zealand construction industry. The report considers international case studies, the latest industry reports, Blockchain primers and information, and input from interviews with leading industry experts, to determine whether Blockchain technology can and should be applied to product assurance and compliance in the construction industry in New Zealand.

3.1 Key questions

The key research question that this study has sought to answer is:

Can Blockchain be successfully deployed for providing an audit trail of relevant, immutable, and trusted product compliance and assurance information in the construction industry, where a diverse and widening range of products are imported?

Three supplementary questions were also developed to support this research, namely:

1. How does the product assurance system in New Zealand currently operate at a practical level in the supply chain?
2. To what extent do suppliers currently use electronic systems to make and record product assurance declarations and to exchange related information?
3. Are there more effective means than Blockchain to gather and secure product assurance in the construction industry?

3.2 Methodology

Our research methodology included a combination of qualitative research, literature reviews of Blockchain and the New Zealand construction ecosystem, interviews with key sector stakeholders (including industry procurement and assurance managers both onshore and offshore) and contributions from technical and information management specialists from within the research team.

Our approach to the research questions was as follows:

Current state assessment

- outline of Blockchain technology, its features and technical trade-offs, security, scalability and extensibility and known applications to date.
- key questions that need to be addressed when deciding whether Blockchain is fit for purpose for construction product assurance and compliance.
- the product assurance and compliance system in the New Zealand construction sector.
- document data requirements (e.g. accreditation, testing and certification) for product assurance (important considerations for Blockchain).
- document industry product assurance and compliance systems (including electronic systems).

Comparative industry sector analysis and case studies, including:

What are the lessons from ongoing pilots in other industry sectors using Blockchain and other data sharing solutions for product assurance? We looked at:

- anti-counterfeiting and product assurance for pharmaceuticals in the United States.
- safety and security of fresh food in its supply chain in India.
- plans of Chinese accreditation and certification authorities.
- Probuild Australia – tracking of building products from China using Blockchain technology.
- Blockchain in New Zealand – New Zealand Honey example.

Future steps for Blockchain technology in the construction sector
We focused on whether Blockchain is the silver bullet by looking at international reviews into the technology while investigating barriers to Blockchain deployment that must be solved before moving forward.

3.3 Report structure

The report begins with defining and describing Blockchain as a business tool. We outline Blockchain use cases by using real-world examples. The section also introduces a Blockchain Decision Tree model provided by The World Economic Forum; a simple framework for assessing whether Blockchain is the right technology solution for a given business problem/issue.

The report then explores a current state assessment of how product assurance operates in the construction industry in New Zealand. This section also outlines the regulatory framework in New Zealand and associated product compliance methods in the New Zealand construction industry.

A section is devoted to outlining specific Blockchain case studies. Examples are drawn from the international pharmaceutical sector and the food sector. We showcase a New Zealand Blockchain example and look at a recent Australian initiative using Blockchain technology to track building products from Australia.

The report concludes by looking at the future steps of Blockchain deployment in the construction sector and outlines some of the current barriers to deployment. We provide recommendations for future research on connecting existing product information databases with the potential to use Blockchain to create a one-stop-shop for product data for the construction ecosystem.

Blockchain – A Short History

The first work on a cryptographically secured chain of blocks was described in 1991 by Stuart Haber and W. Scott Stornetta. They wanted to implement a system where documents' time stamps could not be tampered with or backdated.

Blockchain, in its initial implementation, was invented by Satoshi Nakamoto in 2008 to serve as the public transaction ledger of the cryptocurrency Bitcoin. Replicated ledgers across nodes in the network, ensuring total transparency, and a consensus algorithm to prevent 'double–spends' are core features to this Blockchain network, removing the reliance on a third party such as a bank to exchange value (Bitcoin) between parties.

4 Blockchain technology and its use

4.1 What is Blockchain?

Fundamentally, a Blockchain is a decentralised, distributed record, or 'ledger', of transactions in which the transactions are stored in a permanent and nearly inalterable way using cryptographic techniques (Ganne, 2018, p.VII). This overarching technology includes several supporting technologies built around the distributed, shared ledger of transactions. Algorithms or some other method determined by the Blockchain network facilitate decentralised consensus and are used to validate a transaction and may be written to a public ledger.

The term Blockchain is often used to refer to a particular shared ledger deployed, e.g. 'the Blockchain'. More commonly, even across enterprises that are working on real-world pilots with solution providers, the term Blockchain is used in a generic way.

The hype that has surrounded the term has led many to believe that Blockchain is something that can solve all their business problems. While this is certainly not the case, this hype is sparking important conversations on the topic of data sharing, transparency and trust around the world. These conversations are essential to any success in linking events together across a supply chain in a safe and secure manner.

People often think that Bitcoin and Blockchain are the same thing, but this is not true. Blockchain is an underlying technology layer that enables many potential applications - one of which is Bitcoin.

4.2 Blockchain (or Distributed Ledger Technology)

There are various models of data storage, ownership and exchange, including centralised, distributed and decentralised models in operation today. Blockchain is a decentralised model.

4.2.1 Data storage and ownership

Figure 4-1 outlines the three models of data storage and ownership. In a centralised model of data exchange, parties connect to a central server and write or retrieve appropriate data as determined/ authorised by the central authority governing the system. That authority determines who participates, what they can do, what they can see and how the data is exchanged. It is analogous to a database behind registering a motor vehicle licence or a system that assigns a library card to an individual. If something happens to the central server such as an organisational or system failure where no back-up system has been implemented, the whole system fails. In a supply chain that is dependent on the exchange of data with multiple parties, such an event could have a significant impact.

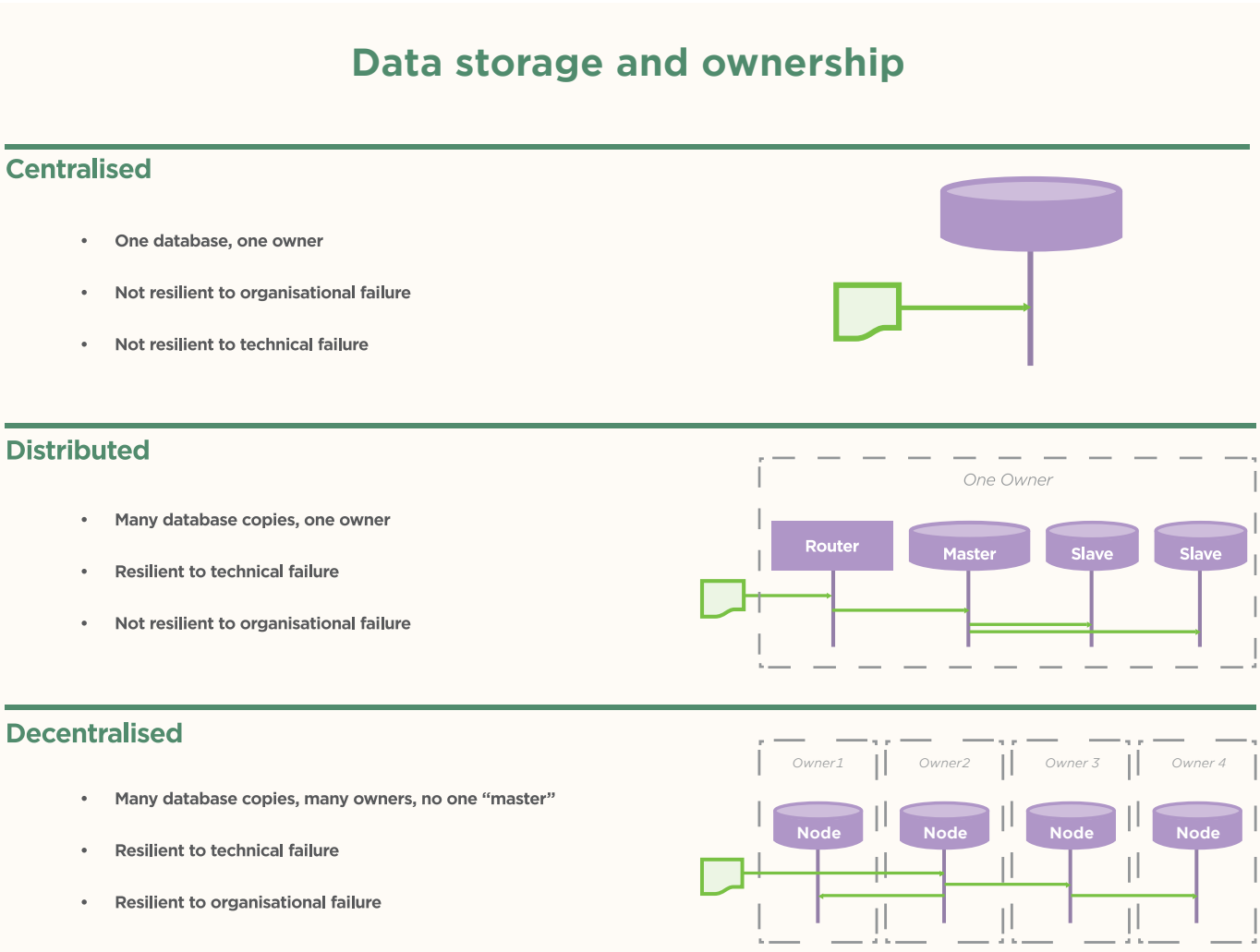


Figure 4-1 - Data Storage and Ownership

Source: *GS1 New Zealand*

In a distributed model, many parties have copies of the data in their respective data repositories, but the system is managed and governed by one central owner – the master. Consider GS1's Global Registry in this example.[2] It manages and governs the exchange of master data between and across data pools and is operated by a single organisation. If there is a technical issue in the registry in updating information changes for example, that trickles down to the data pools ('slaves') connected to the master and data may not be synchronised for a period, although data pools will still have copies to work from.

In a decentralised system – there is no single master. This provides resilience to both organisational and technical failure (GS1 New Zealand, 2018). But in this context all parties need to agree on common rules for how information is added, deleted and otherwise updated.

4.2.2 Data exchange

Figure 4-2 outlines the three models of data exchange. In a centralised model, a party queries the central repository for information. If they are allowed access to the data requested, a response is provided.

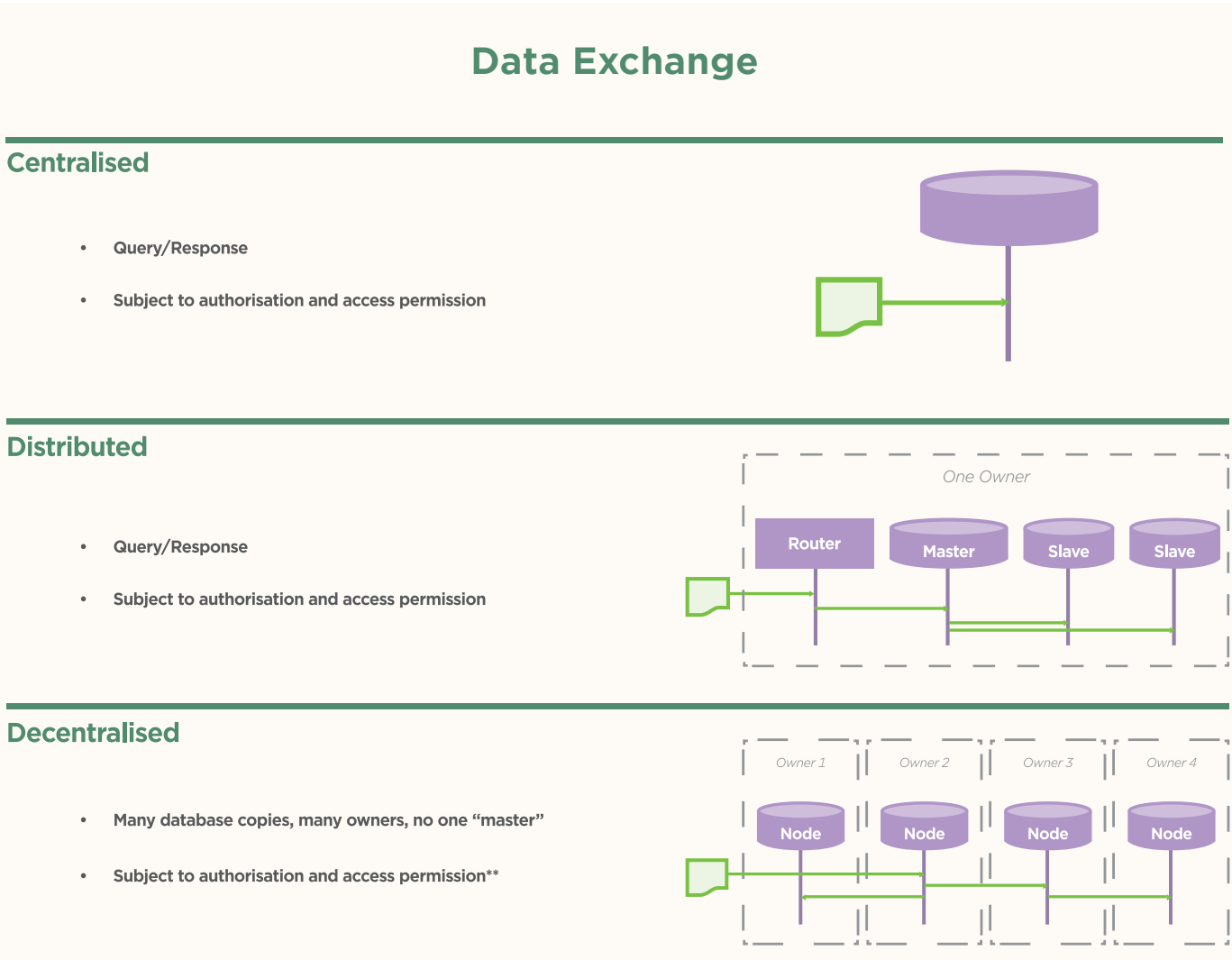


Figure 4-2 - Data Exchange

Source: *GS1 New Zealand*

2 A registry is a place where records are kept. For the purposes of this report, a registry stores data and information about building products. GS1 operates global registries, and is in the process of creating a global cloud of product information to be used by consumers, suppliers, and sellers of products.

In a distributed model, a party sends a request for data which is then routed to the appropriate party for a response. If the responding party has the appropriate authority to access the data and the information is structured in a correct manner, the information is exchanged.
In a decentralised model, every node in the chain has a copy of the data. The challenge arises when changes to data occur and authorisation is required raising the question of data governance et al.

4.2.3 Governance of data exchange

Governance sets the 'rules of engagement' for exchanging data. These rules may decide who gets to participate in the network, the access and permissions to be granted to participants and the data model to be used, as set out in Figure 4-3.

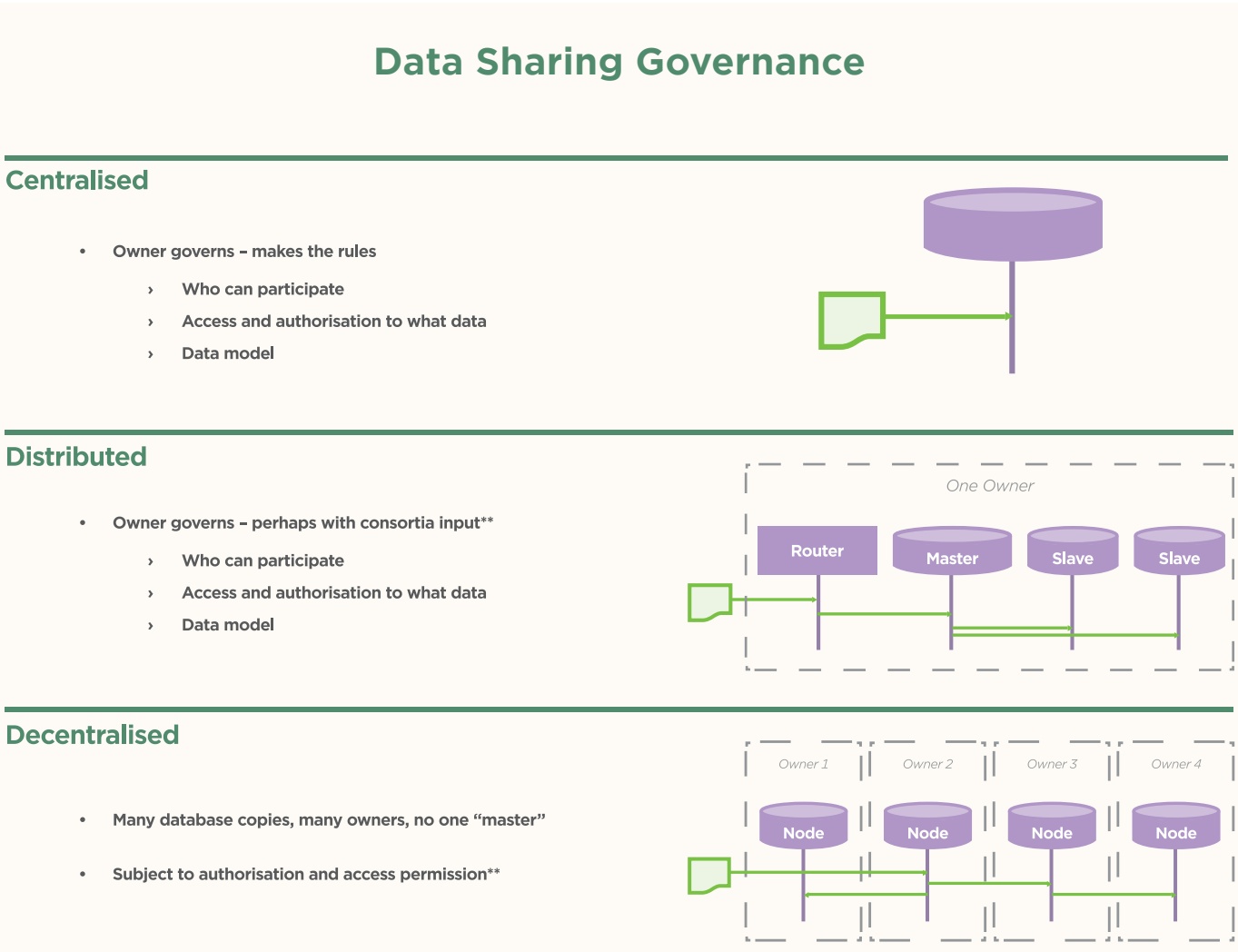


Figure 4-2 - Data Sharing Governance

Source: *GS1 New Zealand*

In a centralised model, data sharing governance is very simple - the rules are developed and maintained by the system owner.

In a distributed model it is similar, however it may depend on the design and rules of the overall network. There is one owner responsible for ensuring the system operates in accordance with the network's governance policies.

A decentralised model, it is more complicated. In a public Blockchain where everyone sees everything and each node has a copy of the data (such as the Bitcoin Blockchain), a consensus algorithm determines whether changes are made or not. Solve the algorithm (a complex math problem that essentially validates a transaction) and secure 51% agreement from the blockchain nodes and a new block is created (resulting in the transaction being written to the ledger). However, the question arises when a rule needs changing. Simply, more mathematical calculations are undertaken within the chain between the nodes and when 75% of those nodes agree on the change, the rule change is implemented.

One of the problems is how this approach works with supply chains. Work is still being undertaken on how the foundational principles of a public Blockchain can work most effectively in supply chain implementations. What is clear, is that supply chain implementation of a distributed ledger relies on limiting access to copies of the ledger which is often referred to as a 'permissioned' or 'enterprise' based Blockchain implementation; a hybrid model mixing distributed and decentralised features.

As the technology evolves, a fully decentralised model for enterprises seems unlikely at this stage; a permissioned based distributed model being viewed as more efficacious. This model is where global efforts are currently focused.

4.3 Blockchain basics: An overview

In the simplest terms, a Blockchain consists of a linked chain that stores auditable data in units called blocks. Each block contains data (anything of value), its own hash value (a unique cryptographic value containing characters and numbers generated through a complex computational algorithm) and a pointer to the hash of the previous block (Sylvester, 2018, p.2).

A public Blockchain is a decentralised, journaled database that records transactions within immutable blocks that accumulate over time and where each block includes a hash value that links it to the previous block, such that as time passes, blocks of validated transactions become confirmed and embedded within a distributed ledger. It is a continuously growing list of records which are combined in blocks that are chained to each other using cryptography[3] (Ganne, 2018, p.1).

Figure 4-4 illustrates how each successive block links to the previous block by including a hash value of the data contained in the previous block.

3 Used to encrypt and decrypt data.

A look at blockchain technology

What is it?

The blockchain is a decentralized ledger of all transactions across a peer-to-peer network. Using this technology, participants can confirm transactions without the need for a central certifying authority. Potential applications include fund transfers, settling trades, voting and many other uses.

How it works

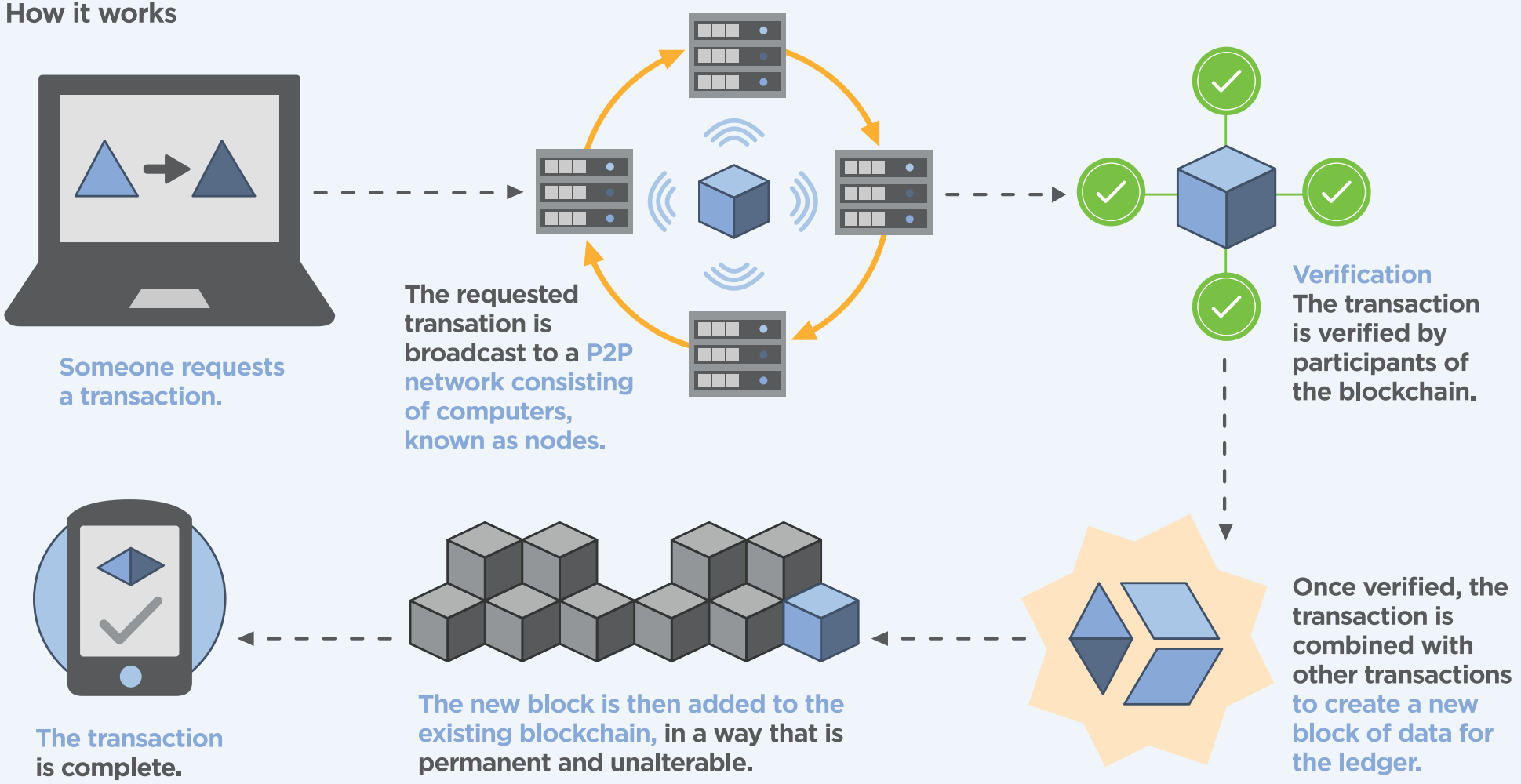


Figure 4-4 - Blockchain Structure and Overview

Source: World Economic Forum

Five common blockchain myths

Create misconceptions about the advantages and limitations of the technology

Myth	Reality
Blockchain is Bitcoin	• Bitcoin is just one cryptocurrency application of blockchain • Blockchain technology can be used and configured for many other applications
Blockchain is better than traditional databases	• Blockchain's advantages come with significant technical trade-offs that mean traditional databases often still perform better • Blockchain is particularly valuable in low-trust environments where participants can't trade directly or lack an intermediary
Blockchain is immutable or tamper-proof	• Blockchain data structure is append only, so data can't be removed • Blockchain could be tampered with if >50% of the network-computing power is controlled and all previous transactions are rewritten—which is largely impractical
Blockchain is 100% secure	• Blockchain uses immutable data structures, such as protected cryptography • Overall blockchain system security depends on the adjacent applications—which have been attacked and breached
Blockchain is a "truth machine"	• Blockchain can verify all transactions and data entirely contained on and native to blockchain (eg, Bitcoin) • Blockchain cannot assess whether an external input is accurate or "truthful"—this applies to all off-chain assets and data digitally represented on blockchain

Figure 4 5 - Five Common blockchain myths

Source: McKinsey & Company, June 2018.

The hype surrounding Blockchain has created several myths, which have led to misconceptions about the advantages and limitations of the technology. Figure 4-5 outlines an analysis completed by McKinsey & Company on five common *Blockchain myths*.

These myths are important to understand. Many people believe that Blockchain is simply Bitcoin. However, Bitcoin is just one cryptocurrency application of Blockchain; the technology can be used for many other purposes. The hype extends to Blockchain being seen as preferable to a traditional database; a misconception. Currently, traditional databases are considered more efficacious than Blockchain for several reasons, one notable reason being that Blockchain's current inability to scale.

The other Blockchain myth is that it is a source of truth. Blockchain can only verify the data stored on the chain; it is not able to verify data quality, accuracy or validity. This applies to all off-chain assets and data digitally represented on the Blockchain. This is important to note when it comes to product assurance. The Blockchain is unable to verify and/or confirm whether product data is accurate and whether the product is compliant.

Furthermore, once inaccurate or false data is loaded to the chain, e.g. a reference to a product certification certificate, it may be difficult to change. While Blockchain immutability may be considered a feature/ benefit in some contexts (e.g. a record of a bitcoin transaction), in other contexts, (e.g. highly specific supply information exchange), this security feature may be considered a weakness.

4.3.1 Blockchain – public, private or consortium

There are three high-level categories of Blockchain implementations that have been identified: public, private and consortium. Figure 4-6 outlines the main characteristics of various types of Blockchains (Ganne, 2018, p.12).

In a public Blockchain network, anyone can read and write to the Blockchain without authorisation. Public Blockchain networks are open to all to participate but this creates the potential for malicious and nefarious users to publish data in blocks in a way that undermines the integrity of the system. To prevent this, public Blockchain networks often utilise a multiparty agreement or 'consensus' system (National Institute of Standards and Technology, 2018, p.5).

Private Blockchain networks limit participation to specific people or organisations and allow finer-grained controls. Permissioned Blockchain networks may also be used by organisations that need to more tightly control and protect their data or transactions.

In the consortium Blockchain, the consensus process is likely to differ to that of a public Blockchain. Instead of anyone being able to take part in the procedure, consensus participants of a consortium Blockchain are likely to be a group of pre-approved nodes on the network. For example, in the construction sector, these could be importers, retailers/merchants and suppliers who have had prior approval.

This is an important distinction to make upfront, as knowing the differences between these two categories allows an organisation to understand which subset of Blockchain technologies may be applicable to its needs (Ibid, p.V). In general, the Blockchain implementations that we explored in a supply chain context are not fully public and are either permission-based or consortium-based.
The likely form of Blockchain in the construction sector will be consortium-based. Within the context of the construction industry, there are multiple organisations supplying products into the market and those participants are identified. While some of the products are designed and manufactured in New Zealand, an increasing number are imported from overseas, including from China.

It is also important to note that the context in which a building product is used is critical to its conformance. In some cases, the use of a product will be essential to the safety and durability of a building; in other cases it may not be as important. The 'code-compliance' of a product may not be immediately obvious; it depends on its purpose/use. Another consideration is the wide diversity of building products available which can range from a simple, single component item, such as a nail, to a complex, multiple component item such as a prefabricated panel with plumbing or wiring pre-installed or even an entire building.

We are not aware of any single organisation in the sector that holds this information in a repository of some sort and a successful blockchain application is highly likely to be consortium based.

Overview of main characteristics of various types of Blockchain

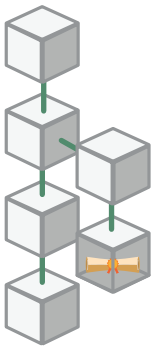
Degree of centralisation	Public		Consortium		Private
Management	**No centralised management**		**Multiple organisations**		**Single entity**
Access	**Permissionless**	**Permissioned**	**Permissioned**	**Permissionless**	**Permissioned**
	Open read/ open validation of transactions	Open read/permissioned validation of transactions	Permissioned OR open read/permissioned validation of transactions	Open read/open validation of transactions	Permissioned read/validation of transactions
Participants	Anonymous/ pseudonymous	Anonymous/ pseudonymous	Identified	Usually identified	Identified
Validation based on consensus protocol	Open to every participant in the network	Open to every participant in the network, subject to certain conditions	By pre-approved participants (across the organisations involved)	Depending on the consensus protocol chosen for the platform	By pre-approved participants (within the single entity)
Speed of validation	Slow	Quicker	Quick	Quick	Quick
Users' level of privacy	None	None	Tailored to the needs of participants	Tailored to the needs of participants	Tailored to the needs of participants
Computing power required (energy consumption)	High (but variable depending on theconsensus mechanism)	Intermediate. Variable depending on the consensus mechanism	Lower	Lower	Lower
Transaction fees	Yes	Yes	Optional – depending on the rules of the blockchain	Optional – depending on the rules of the blockchain	Optional – depending on the rules of the blockchain
Scalability	Low	Slightly higher	Higher	Higher	Higher
Example(s)	Proof of Work (Bitcoin, Ethereum)	Proof of Stake (Nxt)	Blockchains built on Hyperledger Fabric. Permissioned blockchains built on Ethereum	FastTrack Trade	Private blockchains built on Ethereum

Figure 4 6 - Overview of Main Characteristics of various types of Blockchain

Source: Ganne, 2018, p.12

Smart Contracts

Option contract written as code into a blockchain.



Contract is part of the public blockchain.

Smart contracts facilitating trade

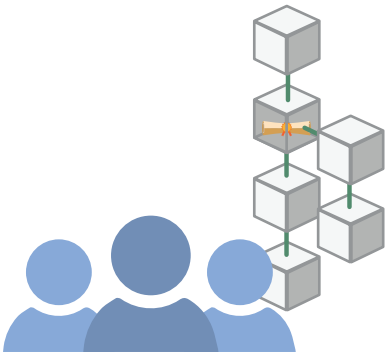
The concept of smart contracts was introduced and developed by Nick Szabo from 1994-1997. It was first introduced into Blockchain in 2015 and forms part of the Ethereum Blockchain (Ganne, 2018, p.13). Szabo defined a smart contract:
A smart contract is a computerised transaction protocol that executes the terms of a contract. The general objectives of smart contract design are to satisfy common contractual conditions (such as payment terms, liens, confidentiality, and even enforcement), minimise exceptions, both malicious and accidental, and minimise the need for trusted intermediaries. Related economic goals include lowering fraud loss, arbitrations and enforcements (Ganne, 2018, p.16).

In addition to transferring monetary value and storing small pieces of data within a Blockchain ledger, some Blockchain ledgers also support 'smart contracts', in which the output of a transaction is linked to a programmatic script or piece of software that is also stored in the Blockchain ledger and is executed by the validation nodes.

Smart contracts extend the functionality of Blockchain distributed ledger technology. A smart contract is a collection of code and data (sometimes referred to as functions and state) that is deployed using cryptographically signed transactions on the Blockchain network (e.g. Ethereum's smart contracts, Hyperledger Fabric's chaincode). The smart contract is executed by nodes within the Blockchain network; all nodes that execute the smart contract must derive the same results from the execution, and the results of execution are recorded on the Blockchain (National Institute of Standards and Technology, 2018, p.32).

Figure 4 7 - Smart contracts ***Source: Ganne 2018 .***

Contract executes itself when the conditions are met.



Regulators use blockchain to keep an eye on contracts.

Parties involved in the contract are anonymous.

In the construction industry there is the potential for a buyer of the building product to have an immutable record of the product assurance data e.g. certifications, at the point of purchase.

A wide range of Blockchain pilots are currently underway globally, as shown in section 6 of this report. The technology is still relatively new and many organisations and governments are considering ways to incorporate Blockchain into their operations or business processes.

Blockchain use cases

There are **six distinct categories of blockchain use cases** addressing two major needs.

Record keeping: storage of static information

Static registry	• Distributed database for storing reference data	**Example** • Land title • Food safety and origin • Patent
Identity	• Distributed database with identity-related information • Particular case of static registry treated as a separate group of use cases due to extensive set of identity-specific use cases	• Identity fraud • Civil-registry and identity records • Voting
Smart contracts	• Set of conditions recorded on a blockchain triggering automated, self-executing actions when these predefined conditions are met	• Insurance-claim payout • Cash-equity trading • New-music release

Record keeping: storage of static information

Dynamic registry	• Dynamic distributed database that updates as assets are exchanged on the digital platform	**Example** • Fractional investing • Drug supply chain
Payment infrastructure	• Dynamic distributed database that updates as cash or cryptocurrency payments are made among participants	• Cross-border peer-to-peer payment • Insurance claim
Other	• Use case composed of several of the previous groups • Standalone use case not fitting any of the previous categories	• Initial coin offering • Blockchain as a service

Figure 4-8 - Blockchain Use Cases

Source: Carson et al, Blockchain beyond the hype: What is the strategic business value? McKinsey & Company, June 2018.

4.3.2 What are the potential Blockchain uses?

Blockchain is used to capture and store data. What data you need to capture, and store depends on the business problem that requires solving.

McKinsey & Company have identified six distinct categories of Blockchain use cases addressing two major needs. Those major needs are record-keeping (storage of static information) and transactions (registry of tradeable information). Figure 4-8 outlines the use cases (Carson et al, 2018).

By far the most straight forward application in the construction sector would be a static registry, containing building product assurance information. While simple in concept, it would need to include evidence that the product is fit-for-purpose under the New Zealand Building Code and in the New Zealand context. That information should include attributes such as product origin and appropriate certification documentation. But there is no industry or regulatory agreement on what the basic information should be.

Even if such an agreement was reached, Blockchain would need to prove its efficacy relative to other competing (and well proven) technologies.

4.3.3 Product provenance and traceability

There is a growing need to provide a clear audit trail of which organisations have undertaken the required tests and activities to check conformance to the New Zealand Building Code (or other codes and standards used to show conformance). In the event that non-conforming products are found, the audit trail could illustrate:

- What specific individual products, or batches of products, were tested, who carried out the testing, and to what standard.
- Who shipped the product from the manufacturing site to the construction site.
- Where the product has been used and how much has been used in builds in New Zealand (Dowdell et al, 2017, p.3).

Many of the Blockchain pilots we have seen are focused on understanding the provenance and chain of custody of products in the supply chain, whether that is tracing fresh fruit back to the field it came from or verifying that a pharmaceutical was commissioned from a legitimate source. A series of events occurring in the lifecycle of a product make up the provenance/ chain of custody story.

To determine the provenance and chain-of-custody of a product, it is essential to understand the following dimensions of a supply chain event in the lifecycle of a product:

- WHAT is it that I want to know about (unique identity of the 'thing' you want to know about)?
- WHEN did the event occur?
- WHERE did the event occur?
- WHY did it occur? (i.e. shipping, receiving, storing etc)
- WHO were the parties involved in the event?

Utilising a data model such as this (GS1's raison d'être) to share data provides the basis to the question "*Where did my product come from, where has it been and when?*"

Data is captured by business applications and can be shared peer-to-peer between trading parties. Systems exist today that capture, store and share lifecycle events. Determining the utility and added value of writing these transactions to a distributed ledger is an important objective for any pilot programme that includes Blockchain as a layer to an overall solution.

During our research with industries around the world, it has become clear that writing comprehensive lifecycle event data (i.e. what, when, where, why, and who) to a decentralised ledger is sub-optimal. Our research identifies that industry best practice is where hash values of off-chain data (such as the lifecycle events described above) are stored on distributed ledgers. This approach ensures that data stored and shared off-chain and peer-to-peer, can be verified as not having been tampered with (regardless of where it is actually stored).

At the core of these emerging best practices is the need for a consistent, standards-driven model (GS1, 2018).

4.3.4 World Economic Forum decision tree

The World Economic Forum has developed a decision tree to help determine if Blockchain is the appropriate technology to use for business issues/problems as shown in Figure 4-9.

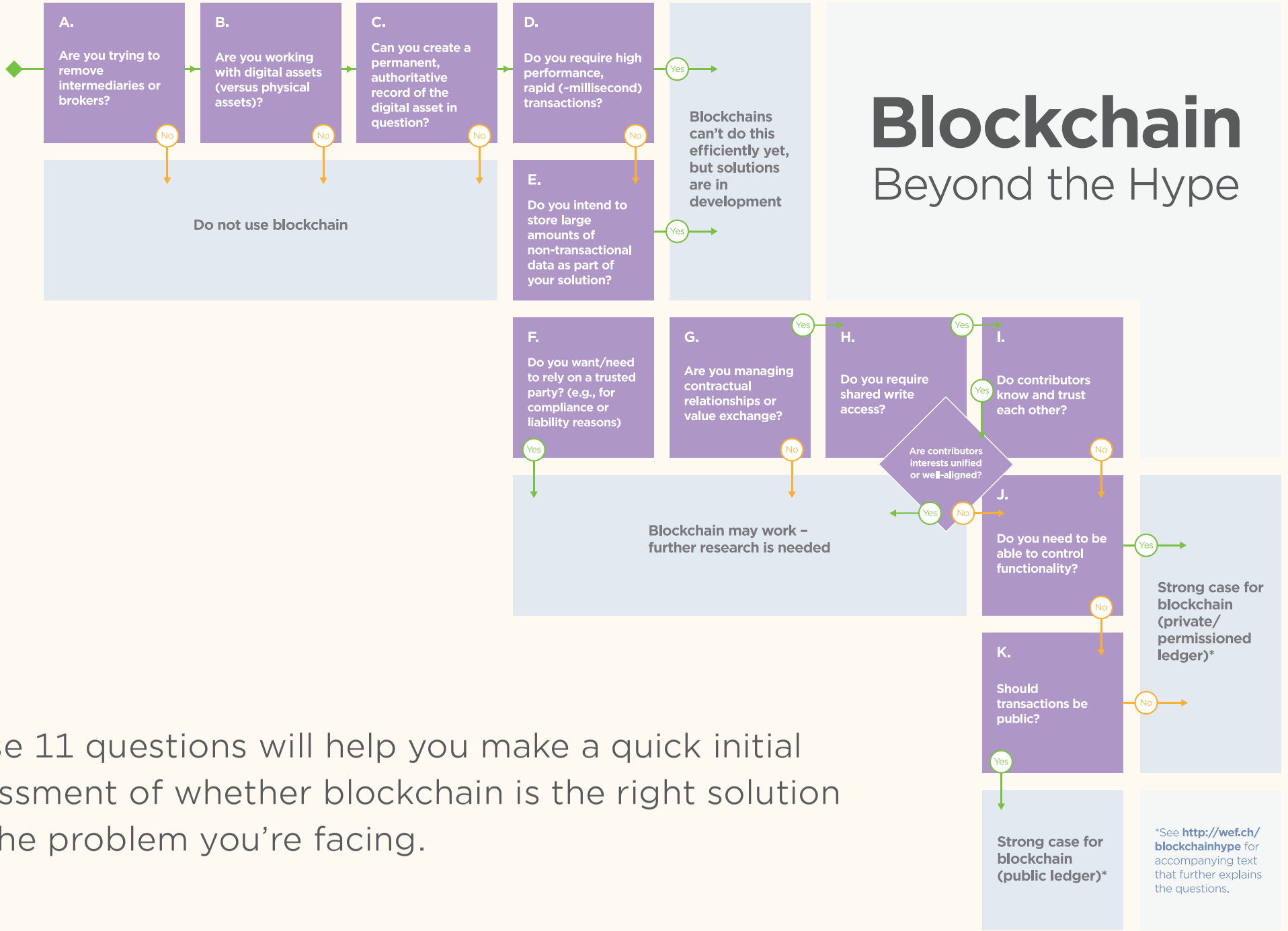
This model is one of many that have been developed to determine whether Blockchain is the right solution for a given business issue.

The decision tree outlines 11 questions and while it is not intended to provide a final authoritative answer, it can assist in evaluating whether or not resources should be allocated into developing a Blockchain-based solution (WEF, 2018, p.6).

Ultimately this model shows that careful analysis is required before embarking on using Blockchain as the technology of choice to solve a business problem.

If high performance is necessary for the application, then a relational database, not Blockchain, may be a better choice. The question should also be asked, does the nature of the transaction really require so many copies of data to be stored on a Blockchain? For the purpose of this research, multiple copies are not required, hence the benefit of Blockchain technology is diminished.

Further analysis on the World Economic Forum decision tree can be found in Appendix 2.



These 11 questions will help you make a quick initial assessment of whether blockchain is the right solution for the problem you're facing.

Figure 4-9 - World Economic Forum: Decision Tree World

Source: Model taken from the World Economic Forum Paper titled: Blockchain Beyond the Hype: A Practical Framework for Business Leaders. April 2018.

5 Construction industry and product assurance today

In this section we outline the current state of the construction sector in New Zealand with a view to understanding the reasons behind product assurance failures. This section will outline problems and challenges of product assurance in the industry today. Understanding the sector is important to assess the value of Blockchain as a potential or partial solution to these problems.

5.1 The industry is large, complex and has experienced significant product failures

The Ministry of Business, Innovation and Employment's (MBIE) Building, Resources and Markets Group argues that a well-functioning building sector will have a positive effect on New Zealand's economic stability, health and security. The sector:

- makes up approximately 6% of New Zealand's annual GDP.
- employed 9.6% of the workforce (December 2016) – nearly 250,000 people.
- drives and supports activity in other parts of the economy such as manufacturing, mining, transport, property and business services. PricewaterhouseCoopers estimates that a $1 investment in construction produces between $2.51 and $3.11 in economic activity (MBIE, 2017, p.4).

The sector has a chequered product assurance history. There have been significant failures in the use of building products and systems. There are ongoing

construction issues today concerning some timber-framed buildings constructed between 1994 and 2004 that suffered from weather tightness cladding problems, with an estimated economic cost of $11.3 billion (2008 dollars).[4] Prior to this crisis there were also major problems, for example, with electrical wiring and polybutylene plumbing systems installed in the 1980s, that continue today as buildings age.

5.2 The regulatory environment

It can be hard to separate building system failures from product failures. Product failures often occur due to the use of products that are not fit-for-purpose, rather than simply being product failure per se. Engineers, designers, builders and regulators need to ensure the use of fit-for-purpose products within the context of different building systems. This is a tough regulatory design and implementation challenge. It is likely a holistic solution is needed that includes a mix of education, training, information disclosure, occupational licensing and other regulatory instruments. Here we cover only those aspects of the regulatory environment that directly relate to product assurance.

5.2.1 General product assurance regulatory environment

There are several laws that affect supplier incentives to address product assurance for all products sold on the market:

- **Fair Trading Act 1986**, which prohibits misleading and deceptive conduct, false representations and unfair practices by people in trade.
- **Sale of Goods Act 1908**, which applies when goods are not covered by the Consumer Guarantees Act. This holds product suppliers responsible for making sure their goods are fit-for-purpose where the buyer has expressly, or by implication, made known the particular purpose the products are required for.
- **Consumer Guarantees Act 1993**, which only applies to goods supplied to consumers for personal, domestic or household use. It requires goods to be fit for their normal purpose, safe, durable and last for a reasonable time.

While designed to protect consumers, in many instances these acts will have limited reach for informing end consumer choice in the construction industry. While product suppliers are responsible for making sure their goods are fit for a known purpose, the assessment of a product's technical features is complex and consumers need to rely on advice from third party experts such as designers and engineers. Providing information to the consumer may be useful but the information is often insufficient.

Problems with building products and systems can take many years to emerge and once products are already in-situ, it is often costly to change them (e.g. plumbing). In addition, the original suppliers may no longer be in the market. In this context it is important to have industry specific regulations and standards that address gaps in general purpose trade and consumer protection law.

4 https://www.interest.co.nz/sites/default/files/PWC-leaky%20homes%20report.pdf

5.2.2 The construction industry regulatory environment

New Zealand has a performance-based building regulatory system. This system enables builders to choose alternative methods so long as they meet performance standards, rather than prescribing how things are to be done and what products can be used.

All work undertaken within the construction industry in New Zealand must meet standards set out in legislation and regulations. These include:

- **Building Act 2004** This is the main piece of legislation governing the building and construction sectors. The aim of the Act is to improve the control of, and encourage better practices in building design and construction to provide greater assurance to consumers. It focuses on the health and safety and general wellbeing of people who use buildings.
- **Building Code** Contained in Schedule 1 of the Building Regulations 1992, this sets the minimum performance standards that buildings must meet. It covers aspects such as structural stability, fire safety, access, moisture control, durability, services and facilities and energy efficiency. The Building Code does not prescribe what products are to be used or work to be done but states how completed building work and its parts must perform.
- **Section 14G of the Building Act - Responsibilities of product manufacturer or supplier** Subsection (2) states that a product manufacturer or supplier[5] is responsible for ensuring that the product will, if installed in accordance with the technical data, plans, specifications and advice prescribed by the manufacturer, comply with the relevant provisions of the building code.

In keeping with the performance-based approach, there are no regulations covering what products can and cannot be used for achieving outcomes. There is no list of approved building products. Suppliers can import products directly into the New Zealand market, without the need for testing against specific building product regulatory requirements. Participants in the industry need to satisfy themselves that a product is fit-for-purpose. To do so, they rely on manufacturer or supplier specifications, testing and use certifications. This flexibility allows developments and innovation in building design, technology and systems but it arguably carries more risk of product failure relative to regulatory systems that require performance testing prior to use in a market.

5 In Section 14 G subsection (1), a product manufacturer or supplier means a person who manufactures or supplies a building product and who states that the product will, if installed in accordance with the technical data, plans, specifications, and advice prescribed by the manufacturer, comply with the relevant provisions of the building code.

5.3 Demonstrating product compliance in the construction industry

There are several ways to demonstrate that a product complies with the Building Code in New Zealand or is otherwise fit-for-purpose for the proposed use. In principle, by demonstrating compliance, suppliers can offer buyers greater assurance of a product's suitability and increase sales.

What a buyer can do with a product depends on the technical product information supporting performance claims and/or test results relevant to the performance required. Assessments vary in rigor and depend on the degree of objectivity or independence from the supplier.

- **Independent assessments for suppliers.** This involves the verification of the product information. Independent assessors can include chartered professional engineers and recognised testing laboratories. The assessor is appointed by the supplier.
- **Industry-based schemes.** These are based on product families or sectors and the product is assessed against specified and audited industry requirements. Examples include ready-mixed concrete which is assessed by the New Zealand Ready Mixed Concrete Association and glass which is certified by the Insulated Glass Unit Manufacturers Association.
- **Second party appraisals.** An appraisal is a technical opinion of a building product or system's fitness for purpose, including conformance with the Building Code. An appraisal organisation should be independent of the product's manufacturer or distributor. It involves extensive testing and verification of Building Code compliance and is done by an independent appraisal organisation. The most widely recognised building product appraisal provider in New Zealand is BRANZ. Since the introduction of the BRANZ appraisals service in 1974, more than 900 appraisals have been issued across more than 1000 BRANZ appraised products
- **Third party product certification.** This product certification scheme provides an easily understood and robust assurance that a building product or system meets certain performance requirements of the Building Code. The product certification scheme was established by the Building Act and is administered by MBIE. The current scheme is known as CodeMark, (MBIE, 2018). The Joint Accreditation System of Australia and New Zealand (JAS-ANZ) accredits certification bodies.

Third party certification is the gold standard; in principle it is the most independent form of assessment. However, it is comparatively costly at approximately $30,000 per product (Gardiner, 2015, p.7). As at 22 May 2019, only 189 products had received product certification under the CodeMark scheme. In a sector containing tens of thousands of unique products, CodeMark certifications and BRANZ appraisals represent a tiny fraction of available products. The small New Zealand market size may not be big enough to warrant suppliers investing in local product appraisals and certifications of new imported products. Substantial reliance is, reasonably, placed on overseas testing and certifications, but these may not always be relevant to aspects of the New Zealand Building Code.

5.3.1 Industry confidence in the product assurance/certification regime

A November 2018 survey that appeared in the New Zealand Hardware Journal shows a low level of confidence in the current product assurance/certification regime. The survey polled those involved across the hardware channel, including retail, builders' supply merchants and product suppliers.

Overall, the survey found that 60% of respondents were less than confident in the current product assurance/certification regime in New Zealand, while 33% were confident. Only 7% were very confident (Bohling, 2018).

Perhaps one of the biggest issues facing the sector is around consent authorities. More than half (53%) of respondents said that inconsistency and delays in approving products and materials were a significant concern. Only 13% said these were not a concern. The same respondents overwhelmingly (80%) said that change in the current product assurance/certification regime needs to happen urgently (Ibid). This sentiment was echoed in the research interviews undertaken for this report.

5.4 The regulatory institutions

The building regulatory system in New Zealand is complex, with many different parties involved in the ecosystem. These include government (MBIE), Territorial Authorities, building professional, tradespeople and registration boards. In principle, all of these parties could have a role to play in using Blockchain technology. Figure 5-1 outlines the different roles in the regulatory system in New Zealand and who carries them out (MBIE, 2017, p.9).

MBIE is the lead policy advisor to government with oversight of several aspects of the building regulatory system

MBIE provides advice on how the regulatory system is performing and suggests changes to improve performance where required. MBIE's central regulator role includes maintaining the Building Code. MBIE is also responsible for other functions listed in Figure 5-1 such as monitoring the performance of Building Consent Authorities, aspects of occupational regulation and providing dispute determinations regarding building matters.

Building Consent Authorities (BCAs) are responsible for the day-to-day implementation and monitoring of building regulations

In New Zealand, most Territorial Authorities (Councils) are BCAs. There are currently 80 registered BCAs. Their work includes:

- checking that applications for building consents comply with the Building Code and issuing building consents.
- carrying out inspections to determine whether building work has been carried out in compliance with a consent and the Building Code.
- issuing notices to fix which require a person to remedy a breach of the Building Act or its regulations.

BCAs are on the front line dealing with product assurance and compliance issues. It is important to appreciate that there is wide variation in their size and capabilities,

Overview of roles within the building regulatory

MBIE	Councils / BCAs	Professionals and tradespeople	Registration boards
Steward & regulator	Regulator	Service provision	Supervision of professionals
System leadership and oversight	Issue building consents	Expert advice and consumer services, eg:	Licensed Building Practitioners
Policy advice	Inspect building work	Architects	Electrical workers
Setting performance requirements in the Building Code	Performance monitoring and enforcement	Designers	Plumbers, gasfitters and drainlayers
Producing guidance on ways to comply with the Building Code	Advice and guidance on systems and processes	Engineers	Registered architects
Performance monitoring	Record keeper	Builders	Chartered professional engineers
Determinations	Provision of property information	Manufacturers & suppliers	Engineering associates
Training and education		NZ Fire Service	
Licensing of some professions			

Building owners – pay building levies, use the regulatory system

New Zealand public – use the building stock

Figure 5-1 - Overview of Roles within the Building Regulatory

Source modified from: Ministry of Business, Innovation and Employment

with some in large metropolitan cities, others in small rural townships. Many may not have the capability to assess whether new products would meet building code requirements and must rely on advice from building professionals and follow standardised processes to ensure building work is compliant.

An example of this is the use of Producer Statements (PSs) which have no status under the Building Act. Producer statements are typically used for specialist work, such as engineering or where there is a proprietary product that is installed by appointed contractors.[6] They are one source of information which the council may rely on to determine whether there are reasonable grounds to conclude that the work complies with the Building Code.

Building professionals, tradespeople, manufacturers and suppliers also have important responsibilities

Building professionals and tradespeople (such as designers, architects and engineers) are responsible for ensuring building plans and proposals conform to the Building Code. They ensure the building is built to any consented plans and are responsible for ensuring building work will meet the requirements of the Building Code (MBIE, 2017, p.11).

The other important group in the ecosystem is product manufacturers and suppliers. They are responsible for making sure their products are fit- for-purpose and are fit- for-use in the New Zealand market as outlined in the Fair-Trading Act 1986.

The final group in the ecosystem is the building user. Everyone in New Zealand has an expectation that the building they use or live in is safe and secure to use. The overarching goal of the building regulatory system is to ensure that buildings are safe, healthy and durable so that people using them can have confidence in their performance (MBIE, 2017, p.12).

6 There are currently four types of producer statement, all with generally widespread council acceptance. They are known as: PS 1 – Design; PS 2 – Design Review; PS 3 – Construction (often used by the installers of proprietary systems); and PS 4 – Construction review.

5.5 The industry speaks: Product assurance and compliance from a practical point of view

As outlined, the research approach included interviews with stakeholders in the construction industry. A list of those interviewed is found in Appendix 1. These were semi-structured interviews, canvassing an array of issues related to Blockchain technology and the New Zealand construction industry in general. Stakeholders interviewed included:

- Manufacturers and importers
- Conformity assessment bodies (CABs)
- Builders
- Building Consent Authorisers
- Retailers

In January 2019, MBIE released a summary of findings titled: Smarter Compliance Pathways: Enhancing clarity, consistency and certainty of the Building Code. The report outlines work that was completed by ThinkPlace on behalf of MBIE, engaging with stakeholders in the building and construction industry to look at the current Building Code system compliance pathways (MBIE, 2019).

The report found nine opportunity areas to help improve the compliance pathway system. One of the opportunity areas involves increasing the ease of understanding of the Building Code system. Respondents came up with several ideas to enhance this, including "exploring collaboration between Masterspec, GS1, Standards NZ, EBOSS and MBIE to create a national library of approved products" (MBIE, 2019, p.13). While this idea will be expanded further in this report, it is important to note that stakeholders have found that a national library of approved building products would help navigate the Building Code system.

Another opportunity area identified is technology enablement. Eight key ideas were expressed in the findings document and one relates directly to Blockchain. The idea is to "utilise Blockchain for Building Code amendments and providing accountability for the producer statement scheme" (Ibid, P.17). While not directly related to this research, it does show that the industry is thinking about Blockchain as a solution to creating a more streamlined and easier to use Building Code.

The construction sector is complicated and overly onerous

One interviewee, working at the coalface of the sector stated that they relied on their suppliers to ensure a product is fit-for-purpose:

> "As a builder, I rely on the likes of PlaceMakers, ITM and others to have done the research to ensure that products I am purchasing from them when building or renovating homes are fit-for-purpose. I personally don't have the expertise to know whether a new innovative product is fit-for-purpose. I tend to use only products that I know work. I tend to shy away from using new products and only will if a customer wants a specific product."

The same interviewee spoke more generally about the sector and said that technological change in how product

data is stored would be useful for their business and would bring about increased efficiencies and productivity:

> “The system currently is overly onerous. There is so much paper and so many hoops required to jump through. A system where you could scan a product and pull up relevant technical information would be excellent. It’s not just about whether a product is fit-for-purpose but wider information would also be useful. I have no understanding of Blockchain and how it works but would find it useful for an app that holds product information and technical data sheets. The information would need to include only the latest evidence that a product is fit-for-purpose. Surely the technology exists currently, we just need some action from the government for this to happen.”

Blockchain is not on the radar

Another interviewee involved at a sector level echoed these comments in relation to Blockchain:

> “No one is talking about using Blockchain as a technological option for capturing data. While it might have its use, I am not sure it is flexible enough. There would need to be a big education drive for Blockchain to become an option. Many link Blockchain to Bitcoin. There are wider issues within the compliance framework that should be looked at before Blockchain is even considered. The major change that is required is it needs to become compulsory for all manufacturers and importers to declare their compliance to the building code. Importers need to be captured as well and they should be required to provide evidence to show that a product is fit for purpose.”

It is difficult to source technical information and this has consequences for innovation

Other interviewees stated it is often difficult to source the technical information about building products and that this level of detail varies between products. Information often sourced from supplier websites that may or may not be up-to-date or there is inaccurate matching to the product in question. There was concern raised that there is limited regulation of building products and because of this, systems are not in place to accurately identify a non-compliant building product. Several interviewees stated that there is not a straightforward relationship between a product, how it is used and how a building performs, and that information about product issues or failures is not shared which makes it difficult to get clear information about how to remedy those issues.

Retailers/merchants have an important role in the system, as consumers assume all products available in store are of appropriate quality and are ready to use on site. This brings a level of liability to the retailer, meaning that some retailers are hesitant to stock new imported building products as they cannot be sure that the product complies with the New Zealand Building Code. Overall, this uncertainty may place limits on the pace of innovation and

sector productivity. While it advantageous to allow for innovation using a performance based regulatory regime, uncertainty over product assurance is not helpful.

There is no consistent and reliable information about building products

Another issue raised on numerous occasions was that there is no consistent or reliable information about building products. There is a general wish across those interviewed to have this reliable information. Knowledge of a product's technical specifications, use, warranties and limitations would be advantageous to the sector. Technical information about building products is often provided inconsistently and not created with the customer in mind. Ultimately, the lack of clarity and inconsistency in this sphere makes it difficult for Blockchain technology to be applied to the product assurance regime. Unless there is regulation with standardised requirements for product information, then it is unlikely that the use of Blockchain technology would succeed in the New Zealand ecosystem.

5.5.1 MBIE Products review update

Part of the MBIE review into Smarter Compliance Pathways was a specific focus on reviewing Building Products.[7]

MBIE met with 46 organisations in July and August 2018 and through this consultation, identified six key issues related to products:

1. The limited regulation of building products does not always effectively prevent or efficiently identify non-compliant building products.
2. Information needed to make decisions about building products can be inconsistent and relies on manufacturers/suppliers to voluntarily provide it.
3. Information about products is hard to verify and requires a technical capability that is not widely available.
4. There are inconsistent practices and a lack of accountability for product substitution.
5. There are limited feedback loops about the performance of products once they have been incorporated into building work.
6. It can be difficult to demonstrate how a product complies with the performance criteria of the Building Code.

These six statements were consistent with what we heard across the interviews we conducted. None of the six statements related to technology which shows that what is on the mind of those consulted is fundamental to the regulatory system and it would be appropriate to rectify these issues prior to any consideration of technological changes to the regulatory system, such as Blockchain.

MBIE has announced a further round of public consultation to address these issues. The consultation will consider these interventions:

- creating an obligation for product manufacturers and suppliers to supply information about their building products and setting minimum standards for that information.
- clarifying roles and responsibilities

7 The review was initiated by the Minister for Building and Construction, Hon Jenny Salesa, who directed MBIE to review the current settings for building products within the building regulatory system to ensure the settings are fit for purpose and that building products, when used appropriately, contribute to safe and durable buildings.

across the building and construction sector in relation to building products and building methods.

- when considering a warning about or banning a building product or method, giving MBIE powers to demand information to support the investigation.
- amending the legislative settings for CodeMark to enable MBIE to be an effective scheme owner and to establish credibility in the scheme.

These interventions will require the purpose of the Building Act 2004 to be broadened to include regulation of building products and their use and to provide clear definitions for building products and building methods.
At the time this report was finalised, MBIE was in the midst of its public consultation. The proposed reform package represents the most significant changes since the current Building Act was introduced in 2004. Part of those reforms specifically concern building products and methods, and aim to:

- clarify roles and responsibilities for building products and methods.
- require manufacturers and suppliers to provide information about building products.
- strengthen the framework for product certification.
- make consenting easier for modern methods of construction, including off-site manufacturing.

These reforms aim to address some of the concerns uncovered in this research. Requiring product manufacturers and suppliers to supply information about their building products will be a good step forward. If Blockchain is to make a useful contribution in the future, it is important that there are clear expectations as to who is liable for supplying the information, and that information is provided in a standardised format.

6 Blockchain deployment: Case studies

There are many pilot studies currently underway globally applying Blockchain technology to policy issues. While this report is not able to cover off these pilots, it provides case study examples where Blockchain technology has been applied.

This report showcases two distinctly different Blockchain application projects. One is focused on the heavily regulated pharmaceutical sector. The other tracks seafood movements out of India, a complete supply chain Blockchain, involving many stakeholders. The seafood Blockchain contains much less regulatory compliance than the pharmaceutical Blockchain.

6.1 Blockchain in the pharmaceutical sector

Introduction

The 2013 US Drug Supply Chain Security Act (DSCSA)[8] prescribes a set of compliance requirements for pharmaceutical supply chain stakeholders over a period of ten years. Significantly, it is a requirement for manufacturers of pharmaceuticals in the United States to serialise (uniquely identify) products at the lowest saleable level. In addition, all supply chain participants are required to share certain elements of master data including product, production, and trading partner information. Of importance to the industry is that in 2023 interoperable, electronic tracing of product at the package level requirements shall go into effect.

8 The United States Food and Drug Administration (US FDA) - www.fda.gov.

Specifically, the US DSCSA requires:

- increased license reporting for Wholesalers and 3PLs.
- exchange of transaction information (TI) and transaction statement (TS).
- systems and processes for verification of product at the package level.
- systems and processes that respond swiftly with TI and TS information.
- systems and processes necessary to swiftly facilitate the gathering of information to produce the TI going back to the manufacturer.
- the ability to only receive saleable returns for products associated to the TI and TS.

Blockchain technology is seen as a potential solution to concerns that retrieving data as far back as the manufacturer could require tens of thousands of electronic connections between previously unconnected participants, where no such electronic system exists. Current Blockchain platforms are said to offer an environment of electronic connections between parties for data distribution, synchronisation and immutability, visibility, security, and, potentially, confidentiality.

DSCSA Blockchain study

In 2017, under the governance of the Center for Supply Chain Studies[9], a study group of regulatory, operations, clinical, IT, and other backgrounds, and from over 50 healthcare industry stakeholders, convened to explore whether Blockchain technology could be used to address all data sharing requirements of the DSCSA TS[10] and to add additional value.

The team established a framework for discussion through the use of computer simulated ReferenceModels™[11] that allowed exploration into governance, technology, services, and supply chain practices relevant to individual stakeholders to aid in DSCSA compliance and to add additional value. For the purpose of the study, the group explored Blockchain capabilities available on many popular platforms, where the data is 'write only' and may be visible to all parties connected to the Blockchain.

Standards usage

Foundational to the study and incorporated in all ReferenceModels was the use of global standards for unique identification, data attribution, process controls, and labelling for sharing data, and to provide the ability to simplify business transactions, improve efficiencies and reduce risk. Standards included GS1 identifiers (including GTIN, SGTIN, SSCC, GLN) GS1 Traceability Standards (including EPCIS) and GS1 Data definitions/dictionary.[12]

ReferenceModels™ simulations

The study used ReferenceModels that incorporated different strategies for leveraging Blockchain technology, and

9 www.C4SCS.org.

10 The DSCSA Transaction Statement is a series of attestations that the transferring trading partners are required to make to those trading partners with whom the product is being sent including the product purchase relationship (i.e. bought direct from manufacturer).

11 ReferenceModels™ are key to the Center's study process. They are computer simulations and diagrams of the supply chain and supply chain stakeholder interactions that explore various design alternatives, regulation interpretations, future states and technology usage. They also help study teams to animate, test and evaluate a current or proposed scenario

12 For a full list of GS1 Standards, please see: https://www.gs1.org/standards

each exposed technical challenges and provided insights into the difficulties of accurately managing product at both the speed and level of granularity needed by the supply chain. A suite of obstacles was encountered that was considered common when transacting business using a visible platform such as Blockchain.

ReferenceModels™ examined

- **ReferenceModel™ 1** In this model (private, permissioned Blockchain), TI and TS data attributes are stored in, or adjacent but accessible to, the Blockchain platform[13]. Supply chain partners provide TI and TS data to a service provider via an 'off-chain' repository (e.g. GS1 EPCIS[14]). The provider, who provides access to the Blockchain, extracts essential data attributes and processes it to post on the Blockchain platform ledger.
- **ReferenceModel™ 2** This model specifies (private, permissioned Blockchain) 'addresses' to data repositories (e.g. EPCIS), portals or other services that are stored in the Blockchain. The Blockchain therefore serves as a 'directory' for access to and retrieval (after authoritative checks etc.) of required data to enable permission-based sharing between trading partners.
- **ReferenceModel™ 3** As with models 1 and 2, this model calls for archival use of trading-partner-supplied EPCIS information (for investigative purposes), however it only stores 'states' of an item as it transitions the supply chain. The model relies on 'on-blockchain' DApps[15] to interpret EPCIS events, archive them and post only the state of the item, the premise being that if DApp code is visible to all, then all can validate and trust the state and be able to make predictable business decisions.
- **ReferenceModel™ 3+** This model expands the state concept of ReferenceModel™ 3 by logically grouping data that may be of interest to query and provides state information at the correct group level efficiently. For example: determining if a product is a regulated product at a product level and not repeated for each package which would show the data each trading partner holds internally, and the data posted to the Blockchain platform.

Findings and observations

The Center's white paper cites the difficulty of searching for information while at the same time constraining access to that information to trading partners that have had ownership. In all models, this resulted in a multi-step process of evaluating queries and determining whether the querying party should have access to the data.

The challenges listed in Table 6-1 were identified throughout the study. The evaluation of the four Reference Models reflects the commentary of the study group participants.

13 At the time of the study it was considered that Blockchain platforms were not designed to efficiently store, encrypt and retrieve large amounts of data and most Blockchains extract a premium for storing data over a set limit.

14 EPCIS is a GS1 standard that enables trading partners to share information about the physical movement and status of products as they travel throughout the supply chain – from business to business and ultimately to consumers. It helps answer the 'what, where, when and why' questions to meet consumer and regulatory demands for accurate and detailed product information.

15 DApps – programme and distributed applications sometimes known as Smart Contracts (could be used to enforce industry and regulatory rules).

Overview of Reference Models

	Reference Model 1 TI/TS Ledger	Reference Model 2 Directory	Reference Model 3 Package State	Reference Model 3+ Expanded State
Supply Chain				
Multiple Company Identifiers	This challenges all models. It can be solved either by strictly using a single Global Location Number (GLN) or Blockchain Account ID per company or by introducing a company hierarchy lookup service.			
Data Access Governance	Must be managed by rules set by industry consensus.	Is managed by individual trading partners in response to TI data queries.	Must be managed by rules set by industry consensus	Must be managed by rules set by industry consensus.
Blockchain				
Obfuscating data on the Blockchain	This challenges all models. The ability to hide data from a blockchain participant while allowing them to query for data, requires special capabilities of a blockchain. The study team discussed and experimented with DApp oracles to encrypt data, zero knowledge proofs and other mechanisms. Some blockchain platforms are developing mechanisms to allow querying and obfuscation through special on blockchain processes.			
Data Storage Limitation	A lot of data is stored in this model. However, private blockchain platforms (vs public blockchains) can manage larger amounts of data.	Minimal data is stored in the model.	Minimal data is stored in this model.	Data is stored across a data model. Each blockchain transaction stores minimal data.
Multiple Platforms	This challenge affects all models. If industry data is spread across multiple blockchain platforms, it is unknown how industry established data access rules would be enforced. There are blockchain/database hybrid solutions and other blockchain-like platforms that may be useful. A single platform may be needed in the near term as the technology evolves and solutions are developed.			
Cost	This challenge affects all models. Whether blockchain tokens or cryptocurrency usage will be acceptable to the industry, traditionally negotiated contracts with service providers or some mix of each will emerge to settle the cost/funding model.			

Table 6-1 - Overview of Reference Models

Source: Center for Supply Chain Studies – The Drug Supply Chain Security Act and Blockchain, June 2018

Public and private Blockchains

As a general principle, private Blockchains are considered safer and more secure than public platforms. Public platforms are hindered by:

- **Performance and storage bloat**
  Public, multi-sector platforms establish contention for rapid transaction processing and require larger storage capacity.
- **Governance risk**
  Governance of public platforms is sometimes challenging as any changes require consensus across multi-industry sectors, which is not always easy.
- **Increased risk of compromise**
  Parties with malicious intent can attack any public or private platform, but public platforms are more open to vectors of attack, unlike private Blockchains that are generally less visible.

However, as we have seen in a number of counterfeiting scenarios, there is always a bad actor inside the legitimate supply chain through which the counterfeits flow. Given this history, we need to treat private or permissioned Blockchains (from a security and confidentiality perspective) as if they are public Blockchains.

Protecting information confidentiality

Most current Blockchain platforms make transactions posted to the block visible to all entities subscribed to the Blockchain. Visibility can be a double-edged sword; it allows for detection of data tampering but also allows visibility for 'trend/ pattern' analysis.

The ReferenceModels all specified that posted data must be obfuscated, however they did not specify how. Techniques explored included encryption, digital signatures and what was referred to as zero knowledge proofs. All have merit and drawbacks in terms of key management and additional services needed. The team also recognised the challenges in establishing confidentiality in an open platform (even in private/permissioned platforms) and the issues that may be encountered in key archiving and transferral as part of mergers and acquisitions.

Governance

Within the context of the DSCSA study, the requirement for an interoperable solution imposes significant demand on industry to establish the governance rules (which may be numerous) needed for compliance. Achieving consensus from all stakeholders along the supply chain could involve thousands of decisions and be both onerous and time-consuming.

The final takeaway from the group is that many of the industry's current regulatory challenges may be successfully addressed as Blockchain (and supporting) technology continues to evolve. Further, with an overarching awareness of the importance of supply chain integrity and protection, the authors believe it is possible to provide effective, secure and innovative ways of doing business with Blockchain technology.

Postscript

In a subsequent study, the Center for Supply Chain Studies delved into the functional needs of a traceability system and, given the constraints of Blockchain identified in the first study, sought to determine a feasible role for Blockchain as part of a traceability system and not as the sole architecture component.

The study found that Blockchain could perform a role in providing audit support in the case of investigating illegitimate drugs

but, at its current maturity level, could not fulfil the information discovery or 'trading partner to trading partner' sharing of DSCSA transaction information. That being said, there is interest in the maturation of Blockchain in the areas of side chains, state chains, and connected, distributed data stores. The programmability aspect of Blockchain platforms remains intriguing and brings with it the challenges of solution co-development.

6.2 From sea to plate: Tracking seafood with Blockchain

Background

StaTwig[16] is an Indian start-up technology company specialising in Blockchain cloud and Internet of Things (IoT) technology to deliver visibility, monitoring, and tracking of products in supply chains. In 2017, StaTwig participated in the Smart Village program[17], a project in conjunction with the University of California, Berkeley and the Government of Andhra Pradesh (India).

This program addresses the problems of technology firms attempting to apply their solutions to the rural setting of India. Its objective is to let innovative corporations and start-ups tap into emerging rural markets, to accelerate their business and to create value for rural populations at the same time. The scope of StaTwig was to improve the visibility, monitoring, and tracking of product in the seafood supply chain. The project traced the journey of fish caught by subsistence farmers of the Andhra Pradesh region in India, through the Indian supply chain to export markets in Asia and the United States.

The main concerns the project attempted to address involved food safety and food waste attributable to poor food quality, counterfeit products, and supply chain (principally cold chain) failure. The project included monitoring the temperature of seafood packed in tamper-proof containers as it moved along the supply chain.

Using their Blockchain platform[18] and IoT technology, StaTwig was able to demonstrate how trust, transparency and authenticity can apply throughout the entire supply chain, to improve food safety, reduce waste, and address counterfeit product authentication and provenance issues, while improving product margins for trading partners and meeting food safety compliance requirements.

The Sea to Plate study

The supply chain used in the study represented a typical stakeholder community involving producers, distributors, retailers, and consumers, as outlined in Figure 6-1.

16 https://statwig.com/#

17 See https://smartvillagemovement.org

18 Known as scBlockchain

Figure 6-1 - Seafood Supply Chain Seafood ***Source:*** https://statwig.com/#

The data collected at each supply chain node includes contract information agreed between the trading partners. Typically, contract information was non-existent, paper-based or stored insecurely. Populating this information into a Blockchain, therefore, was seen to provide the opportunity to improve this situation.

Consignment temperature information was also dynamically captured and recorded at each supply chain node, thereby providing actionable visibility throughout the journey. Product cartons were uniquely identified using GS1 product identifiers and barcodes.

These data were loaded into the scBlockchain which is a permission-based platform, rendering it both secure and immutable. Additional supply-chain-related information was also captured and recorded as outlined in Figure 6-2.

Figure 6-2 - A model for Data and Work Flow ***Source:*** https://statwig.com/#

The scBlockchain Platform

StaTwig's scBlockchain platform is built using open source[19] Blockchain infrastructure (e.g. Ethereum[20] , Hyperledger[21] , Multichain[22]) and a suite of scBlockchain services deployed to manage data inputs while enhancing a system's scalability and interoperability, and improving reporting performance, as set out in Figure 6-3. The solutions layer provided includes interfaces for supply chain visibility, shipment monitoring, and tracking.

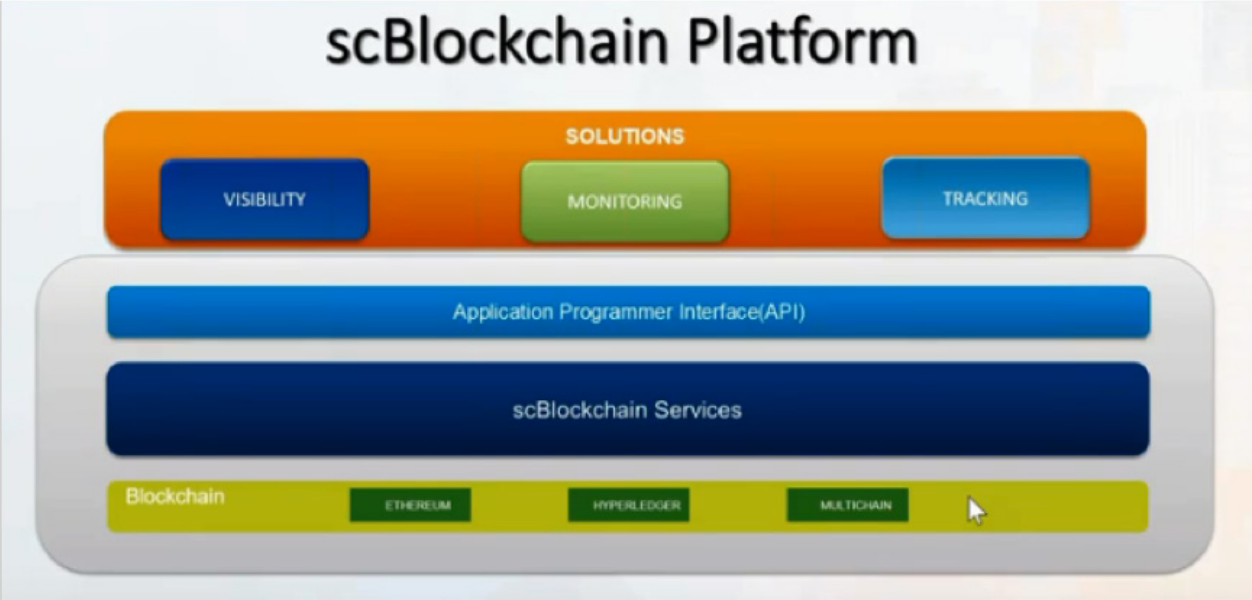


Figure 6-3 - scBlockchain Platform ***Source:*** https://statwig.com/#

Fish supply chain – situation analysis

The process, as shown in Figure 6-4, started with 15 local fishermen harvesting fish using traditional, small, fishing boats. Fish were stored in a temporary warehouse each day at the local port (Antervedi) in preparation for the daily local buyer's market. Typically, there are no catch/ sales records exchanged between fishermen and buyer, meaning such things as fish type, quantity, and quality information is not captured nor recorded.

The local buyers engage with national buyers/distributors for the sale and purchase of the catch, but there is no discussion on price; price is determined at the sole discretion of the national buyer.

19 Open source denotes software where the original source code is made freely available and may be redistributed and modified.

20 Ethereum Blockchain focuses on running the programming code of any decentralised application. In the Ethereum Blockchain, instead of mining for bitcoin, miners work to earn Ether, a type of crypto token that fuels the network.

21 Hyperledger is an open source collaborative effort created to advance cross-industry Blockchain technologies. It is a global collaboration, hosted by The Linux Foundation, including leaders in finance, banking, Internet of Things, supply chains, manufacturing, and technology.

22 MultiChain technology is a platform that helps users establish a certain private Blockchain that can be used by the organisations for financial transactions.

Fish is transported in carton boxes from Antervedi to the national buyer using the Indian train network and is typically a two-day transit. There is no visibility of the fish during transit and there is no refrigeration. When the product arrives at the national buyer's premises, the fish is inspected, and a price advised to the local buyer. Fish is then prepared for export.

Figure 6-4 - Fish Journey

Source: https://statwig.com/#

Stakeholder challenges

The lack of information shared between the trading partners shown in Figure 6-5 outlines the different challenges – and potential areas for dispute and conflict – for each of them. It also signals the opportunity lost for each stakeholder in being able to manage, develop and grow their respective businesses.

Figure 6-5 - Stakeholders involved in the supply chain

Source: https://statwig.com/#

Phased implementation

The project is being implemented in phases. This analysis focuses on Phase 1, getting the fish from the sea to the processing plant.

Phase 1: Sea to processing plant (includes fish harvest, fish auction, export shipping)
Objective – to track fish from the point of harvest (authenticated provenance) to the point of export, focusing on fish quality using a controlled, monitored temperature environment to:

- achieve improved demand/ capacity forecasting
- establish robust contracts between trading partners, and
- authenticate provenance.

Each fisherman was provided with an Android mobile phone[23] using local language, with a pre-installed APP to enable the capture and recording of product information and supply chain data. The information was submitted to the scBlockchain using the mobile phone application (Figure 6-6).

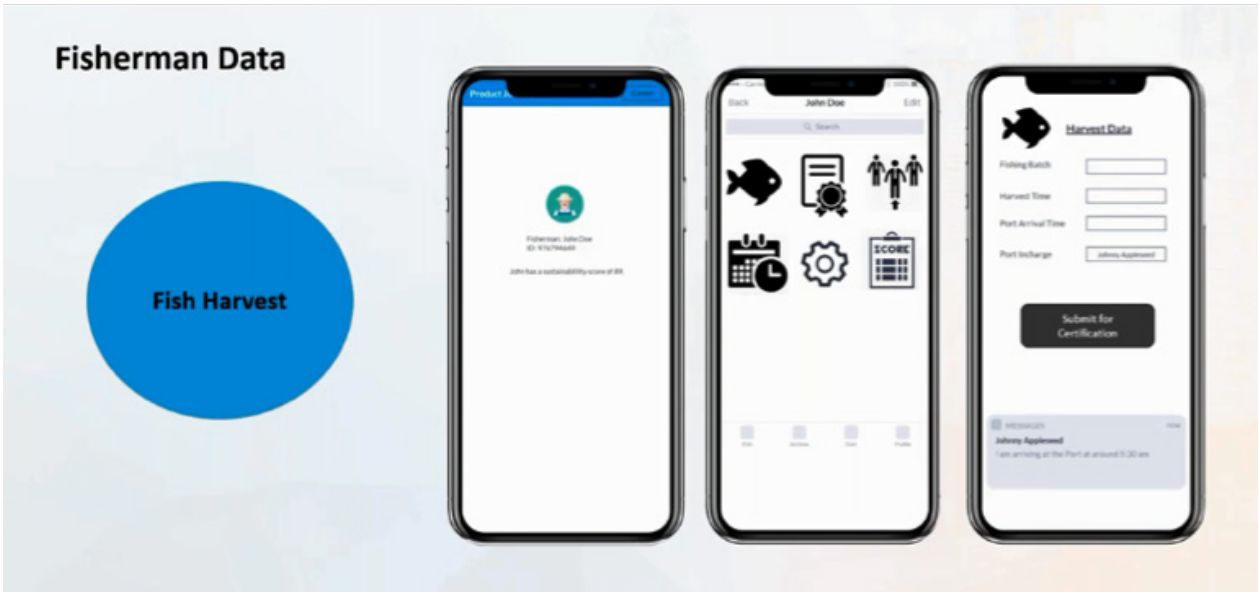


Figure 6-6 - Fisherman's data sent to the scBlockchain using mobile phone allocation

Source: https://statwig.com/#

Fishing inspectors at each port collect, inspect, certify, and issue certificates prior to the daily local market opening, see Figure 6-7.

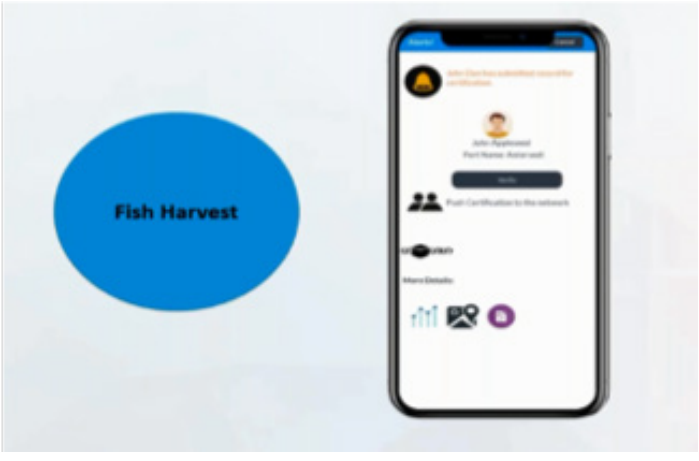


Figure 6-7 - Fishing inspector's mobile device for recording information

Source: https://statwig.com/#

23 Mobile phones and data packages are generally very cheap commodities in India.

Certificates issued by inspectors are digitised (see Figure 6-8) and transmitted onto the scBlockchain using the mobile phone application.

Figure 6-8 - Fishing inspector's mobile phone with digitised certificate ***Source:*** https://statwig.com/#

The fish bidding process is digitised using mobile phones, see Figure 6-9. Local market buyers were able to view the inventory of each fisherman and bid accordingly. The bid is recorded on the scBlockchain, see Figure 6-9.

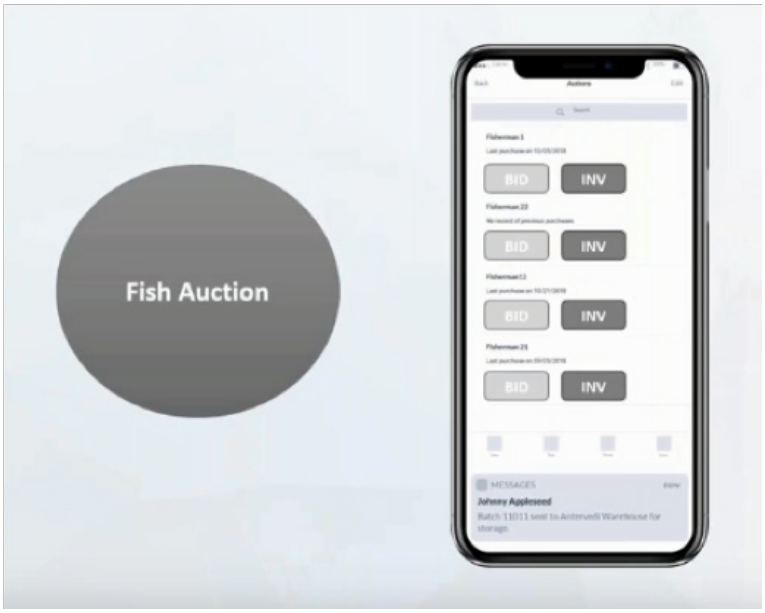


Figure 6-9 - I-Inventory and bidding – mobile phone screen ***Source:*** https://statwig.com/#

Once the local market buyers have ownership of the fish, it is shipped. Figure 6-10 outlines the consignment shipping information displayed in real time and highlights the shipping status and any shipment alert (e.g. pre-set temperature variation). Alerts are available to all trading partners with access rights to the scBlockchain. Alerts initiate consignment checking procedures at any networked supply chain node. Only 'important' (i.e. pre-set) notification alerts are loaded to the scBlockchain and the stakeholders are also alerted.

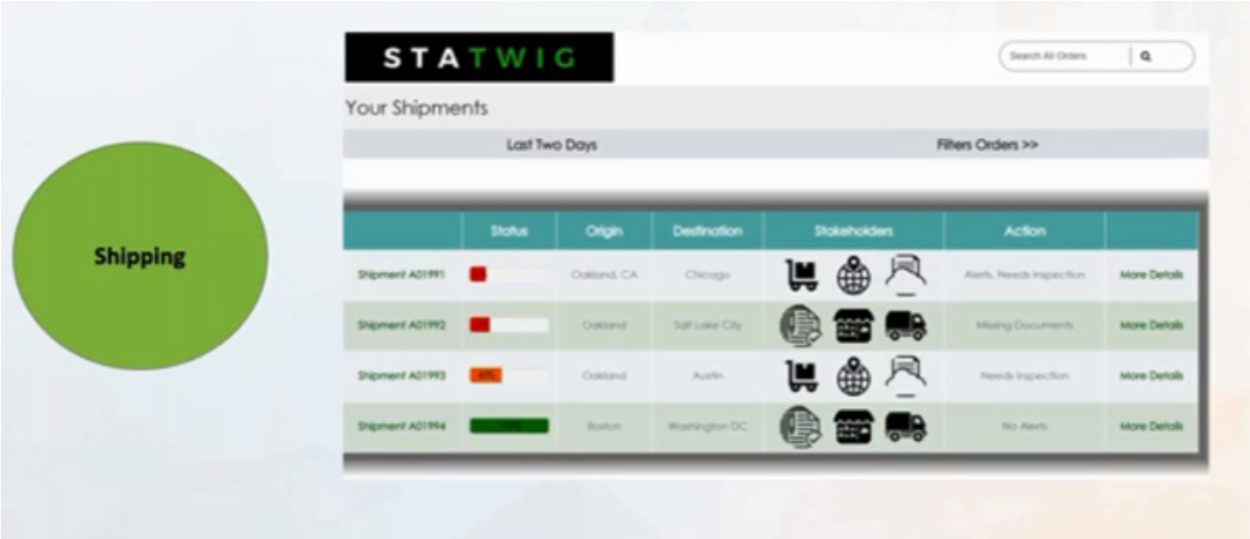


Figure 6-10 - Shipping information ***Source:*** https://statwig.com/#

Conclusion

By using Blockchain technology, the researchers see they are adding different value propositions to different stakeholders in the supply chain. For fishermen and local buyers, this translates into improved profit opportunities; having more enhanced, readily available, and accurate product information allows for improved negotiating opportunities regarding price. National buyers have enhanced supply chain visibility enabling them to sell authenticated, premium quality product in international markets. Shipment tracking enabled all packages to be tracked between Antervedi and Kolkata (Indian port), a total of 1032 shipments. A total number of 3943 alerts were generated, enabling almost real time corrective action to be taken.

Notwithstanding the use of the open source Blockchain infrastructure that the scBlockchain is built on, interoperability between Blockchain platforms generally remains an unresolved issue at this time. Interoperability is an important factor to consider if Blockchain is to be extended into wider supply chain transactions e.g. retailers and consumers.

6.3 Probuild Australia and Brickchain

In September 2018, Probuild Australia announced it was teaming up with Blockchain start-up Brickchain to introduce Blockchain technology to its supply chain from China. This is Brickchain's most significant supply chain management deal to date. Australia's Probuild is a more than $1 billion revenue company, and one of Australia's largest construction firms.

Founded in 2017 by Bassem Hamdy and Ron Goldshmidt, the Southern California-

based data management and Blockchain product Brickchain aims to transform how we interact with the built worlds around us. By ensuring data integrity and provenance, Brickchain powers information and data layers for real assets, bringing buildings to life, and enabling massive productivity gains and powerful data management solutions in real time. Like all Blockchain pilots, Brickchain's mission is to digitise, organise, and curate the world's building data by using the disruptive power of Blockchain.

Brickchain was the first ever company to publish a digital twin of a physical building on Blockchain and has continued to innovate through integration with WatsonIOT, IBM Cloud and other technologies.[24]

Managing Director of Probuild Australia Luke Stambolis stated:

> "Brickchain has a mature Blockchain and the domain expertise to help power our supply chain verification processes from China, to Hong Kong on to Melbourne and then live time installation. We now have the Blockchain as the source of truth, triggered by Ynomia's BLEAT IoT technology across the seas. Probuild will now shortlist a Banking partner who will securitise the entire process. We're very excited."

Bassem Hamdy, CEO of Brickchain, sees this partnership as a validation of Blockchain's adoption in what has traditionally been a conservative industry:

> "Probuild has the vision that Blockchain, IoT and Big Data can revolutionize the construction supply chain. We look forward to transforming the industry with Ynomia and Probuild[25] ."

In theory, construction projects rely on various parties to work together to complete a building based on pre-defined specifications. Each party expects payment based on work done. The peer-to-peer connectivity of Blockchain, combined with smart contract functionality, brings potential opportunities to better co-ordinate construction project management.

Blockchain also offers the opportunity for a piece of real estate to come with its own permanent record of past inspections. Blockchain data is immune to tampering by any party who may have an interest in ensuring a structure passes muster. Similarly, Blockchain could also record any structural or maintenance work undertaken on the property over its life cycle. However, as will be outlined in the next section, the technology is still immature and there are several barriers that would need to be overcome for this to become a reality. However, the Probuild Australia announcement is the first of its type in the construction industry and an initiative that the New Zealand industry should follow closely.

24 Multiple attempts were made to interview Probuild Australia for this research. Unfortunately, arrangements for an interview were unsuccessful.

25 Case study information taken from online announcements including: TechStartUps Team - https://tech-startups.com/2018/09/25/blockchain-startup-brickschain-australias-probuild-join-forces-bring-construction-blockchain-across-supply-chain/.

6.4 Blockchain in New Zealand: New Zealand Honey

New Zealand has a strong history of producing high quality exports, especially in the food industry. This is due to the stringent quality and ethical standards that industries and government have implemented. However, once exports leave New Zealand they face competition from fraudulent imitations in the international market. New Zealand suppliers have higher costs of production but can't realise higher prices in export markets as they struggle to achieve product differentiation. They also face reputational harm to their brands through counterfeiting. Last year four times the amount of 'Manuka Honey' was sold in foreign markets than New Zealand actually produced. (Centrality, 2019).

The Pilot Solution

The Blockchain concept is still new in New Zealand. One Blockchain development that is underway is a joint initiative between New Zealand Post, AsureQuality (AQ) and New Zealand Trade and Enterprise for the HUI Maori Collective. They have joined forces with Alibaba, TrackBack, and Sylo to provide an export and tracking service for food producers (Callaghan Innovation, p.17). The project is currently in the pilot phase and is essentially a delivery system for New Zealand products bought online, which includes a digital record of where each product has come from.

As a pot of honey is produced from a batch, an individual identifier is assigned to that pot of honey and registered on the Blockchain. The honey then moves to the New Zealand Post pick and pack facility where it is stored, waiting to be ordered through the Alibaba e-commerce site. Once ordered, the New Zealand Post team use a Decentralised Application (DApp), created by TrackBack, to link all relevant data, and assign a unique parcel identifier. This identifier tracks the parcel from New Zealand, through to the end consumer in China, capturing all supply chain events along the way. Once the package is opened by the end consumer, they can scan each pot of honey on their mobile device to see the honey certifications, as well as the supply chain journey (Centrality, 2019).

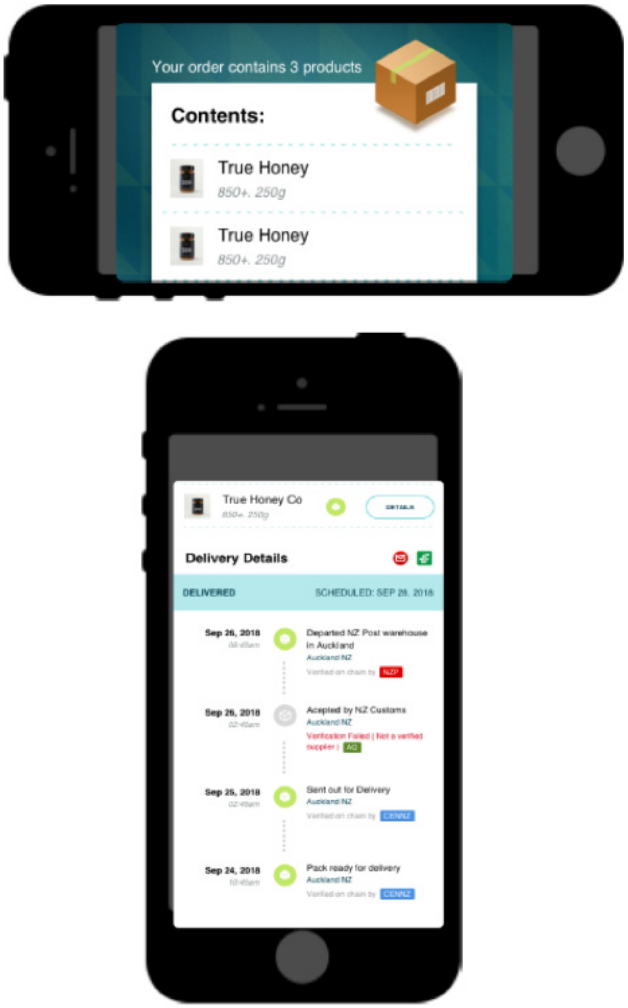


Figure 6-11 - TrackBack DApp in action

Source: Centrality

For example, a woman in Shanghai buying a pot of manuka honey for her mother through Alibaba will be able to check that it is real Manuka honey. Trust – or the lack of it – is one problem New Zealand small and medium-sized enterprises (SMEs) face going into the Chinese market. There are a lot of fake, and sometimes dangerous, food products being sold there (Mandow, 2018).

This project has multiple benefits, including:

- **Provenance tracking**
  The history of the project from its origin to its current location can be traced. This helps prove the authenticity of the product.
- **Increased visibility and control**
  By providing a permanent record of the product's history, trust and visibility are created resulting in extra benefits for the supplier, including identifying product issues.
- **Cost reduction**
  Reduced administration by replacing paperwork with smart contracts across the supply chain provides savings within the cost of sale for a supplier.
- **Creating new ways to trade**
  Blockchain verification creates trust and transparency, enabling the development of new economic models. Suppliers can find direct methods to market, such as cross-border e-commerce, enabling savings over traditional trade models (Centrality, 2019).

TrackBack's partnership with NZ Post, AsureQuality, and Alibaba has led to the development of a useful traceability and provenance tool to combat the Manuka honey counterfeiting issue and provide a single source of truth for the end consumer (Ibid). However, time will tell whether this initiative is fully adopted and commercialised.

6.5 Case study insights

While there are a wide range of Blockchain case study examples, the scope of this research meant that not all potential use cases of Blockchain technology were able to be analysed. Two vastly different case study examples were analysed, alongside a New Zealand example.

In summary, Blockchain is a potential solution to at least some existing business problems. Through studying these examples, several things became clear. The governance of the Blockchain is vitally important and must be determined at the beginning of the project.

Some industries, such as the pharmaceutical and construction industries, are heavily regulated and will require a vastly different governance structure compared to others. Governance of public platforms is challenging, as any changes require consensus across multi-industry sectors, which is not easy. Therefore, a consortium-based Blockchain would be preferable for the construction industry. However, as shown in the pharmaceutical case study, this is not easy to achieve.

Supply chains can become very complicated very quickly and having buy-in from across the sector is important. This is not a Blockchain-specific problem, but a coordination problem, and it came through in the interviews that were conducted for this research.

Increasingly, Blockchain interoperability will become an issue – it is one of the major concerns of Blockchain development, and it remains an unsolved issue. This will be discussed in greater detail in the next section of this report.

7 The future of Blockchain in the New Zealand construction industry

The case studies cited in the previous chapter uncovered several issues when it comes to Blockchain adoption. The pharmaceutical sector case study discussed issues with governance of the Blockchain. That sector is not unlike the construction sector in that both industries are heavily regulated, and both operate within diverse and complicated supply chain ecosystems.

The final section of this report builds on the case study examples provided and outlines some of the barriers to widespread Blockchain adoption. This draws on other government sponsored research on Blockchain, which are largely independent of the assessments offered by solution providers.

7.1 Government research findings

Several government reports have been undertaken on blockchain technology, as outlined below.

7.1.1 Blockchain in New Zealand – Callaghan Assessment

A 2018 report commissioned by Callaghan Innovation titled Distributed Ledgers and Blockchains: Opportunities for Aotearoa New Zealand provided a first look at the technology and its potential use (Callaghan Innovation, 2018). The report was co-branded with Centrality, a leading New Zealand based fintech venture that leverages a blockchain platform.

The report did not focus on the construction sector but provided an outline of several potential use cases across government. It recommended the following for government and the private sector in New Zealand:

- convening a cross-agency Blockchain working group.
- unblocking access to banking services for Blockchain companies.
- promoting New Zealand as Blockchain friendly.
- growing technology industries in regional Aotearoa New Zealand.
- focusing on security tokens.
- establishing a multidisciplinary research centre for decentralised computing
- establishing a Blockchain financial crime prevention forum.
- prioritising digital identity adoption and digital inclusion (Ibid, p.9).

These recommendations are very much focused on promoting and establishing Blockchain within the New Zealand technology ecosystems, with a focus on fintech and research.

7.1.2 Government research findings - international

The Australian Digital Transformation Agency is currently undertaking research into the potential of Blockchain and distributed ledger technology (DLT). It was awarded AU$700,000 to undertake this research.

In October 2018, Chief Digital Officer Peter Alexander reported back to the Australian Senate Finance and Public Administration Legislation Committee the preliminary findings:

> “I would say our finding of Blockchain is that it is an interesting technology and a set of technologies from ledger to programmable currency... It would be our position today, and this is early in our write-up of this, that Blockchain is an interesting technology that would be well worth being observed. But, without standardisation and a lot of work to come—for every use of Blockchain you would consider today, there’s a better technology—alternate databases, secure connections, standardised API engagement. Blockchain is an interesting technology but it is early on in its development.
>
> It’s at the top of a hype cycle, and the uses of it—outside trust—and I should be really clear: one of the advantages of Blockchain is it is great for low-trust engagement. But, generally speaking, when government is engaging with someone, we want to have a trusted relationship with them. We want to know who they are, we want to know what they’re entitled to and we want to

give them a service that is personalised and meets their need. Blockchain is good for low-trust engagement, where you don't know who you're dealing with, you have low trust with that person or business, but you have a series of ledgers that can give you some validation and some support (Commonwealth of Australia, 2018, p.11).

I want to say, to be clear, we're not saying Blockchain doesn't have potential; it's just today, without standardisation, there is a challenge of Blockchain becoming a little fragmented. When we get into a standardised world of Blockchain, which is coming—Standards Australia are looking at Blockchain, as in a standard set for Blockchain domestically and internationally. When we get to a better standardisation, the opportunities for Blockchain will grow (Ibid, p.16)."

Alexander went on to state that the Australian government is at a similar state to other progressive nations:

"I would say that the Australian government is at a pretty similar state to most progressive governments: looking at Blockchain, trying to understand it, doing examples, doing prototypes and doing testing of the technology. I think it would be fair to say a lot of big vendors and technology vendors are pushing Blockchain very hard. They see sales opportunities in it. Internationally, most of the hype around Blockchain is coming from vendors and companies, not from governments or users and deliverers of services who are saying, 'Blockchain's the solution to our problem' (Ibid)."

Kevin Werbach, the Professor of Legal Studies and Business Ethics at Wharton University of Pennsylvania, at a recent Spring Policy Forum in Washington, made several comments about Blockchain and government. He stated:

"This is a new infrastructure baseline technology that can lead to lots of benefits – also, it has lots of problems. Blockchain is now a source of a great deal of fraud, of illegal activity and regulatory arbitrage, but it is also sparking innovation across the world in all sorts of areas.

To be sure, Blockchain is still in its early stages. Many of these will fail. But if you could go back 25 years ago, to the early 1990's, and you knew what the internet was going to become what kind of bets would you make? It took 20 years for all this to unfold. Something similar will happen with Blockchain. We're at that point now where we can start to see the potential, and so therefore this is the time for public sector agencies as well as enterprises in the private sector to start to experiment and figure out where the real opportunities are, where this technology can actually solve problems in new kinds of ways. So that's where we are today and it's a very exciting

time (Knowledge@Wharton, 2018)."

The United States National Institute of Standards and Technology (part of the U.S. Department of Commerce) makes the following recommendation in their October 2018 report titled Blockchain Technology Overview:

> "Blockchain technology is still new and should be investigated with the mindset of "how could Blockchain technology potentially benefit us?" rather than "how can we make our problem fit into the Blockchain technology paradigm?". Organisations should treat Blockchain technology like they would any other technological solution at their disposal and use it in appropriate situations (National Institute of Standards and Technology, 2018, p.VI)."

The Department of Homeland Security in the United States, in its 2018 report titled Blockchain and Suitability for Government Applications, makes four recommendations:

1. Blockchain has multiple challenges to overcome in realising its full potential. These challenges include scalability, data security, interoperability, governance and the management of personally identifiable material.
2. Blockchain is best suited for use cases requiring at least three of the following: data redundancy; information transparency; data immutability; and a consensus mechanism. If only one or two are required then blockchain may work, but there are likely simpler or cheaper ways to solve the problem.
3. A permissioned Blockchain may be a better option for government use since all parties afford some degree of trust to a central authority, permitting selection of a consensus mechanism that is more efficient and less expensive compared to a permissionless Blockchain.
4. Blockchain is not a silver bullet for the US Government; however, there are areas of government interest where distributed ledger technology appears to be well-suited to delivering specific and tangible benefits. These include public records, budget allocation, supply chain monitoring, and the government approval chain process (Department of Homeland Security, 2018, p.5).

These recommendations are sound and outline the current state of Blockchain technology in a global context. The focus on the technology today is on more of a permission-based Blockchain, rather than the pure fully-decentralised Blockchain.

7.2 What are the technical barriers to Blockchain deployment?

The EU Blockchain Forum introduced a report titled, Scalability Interoperability and Sustainability of Blockchains and cited three challenges that need to be overcome. These challenges are:

- **Scalability** – the ability to handle large volumes of transactions at high speeds.
- **Standardisation and Interoperability** – the ability to exchange data with other platforms, including those running different types of Blockchains, as well as with the off-chain world.

- **Sustainability** - including the ability to run large-scale Blockchain platforms or decentralised applications in an environmentally responsible way, and the ability to govern projects, platforms and the core technology in such a way that they remain viable over the long term (EU Blockchain Forum, 2019, p.5).

The EU Blockchain Forum stated:

> "We believe that projects need a clear vision of what they want to accomplish, a clear reason for using Blockchain instead of traditional database technology, and strong governance structures that provide clarity on roles and responsibilities (Ibid, p.6).

This statement aligns with many other statements we have heard. Business problems need to be identified, and if existing database technologies can't solve them, then alternative technologies like Blockchain could be researched, and possibly pursued. As the hype around Blockchain continues to reverberate, finding answers to questions around scalability, interoperability, and governance has become more important.

7.2.1 Scalability

Scalability issues have been identified as the main reason why enterprises have not yet been able to efficiently implement Blockchain. According to a recent survey, 40% of executives see scalability in Blockchain technologies as a major issue for enterprise implementation (GS1, 2018).

Being able to effectively support many users on the Blockchain network is the major issue. Both Bitcoin and Ethereum, the leading Blockchain networks, have experienced slowed transaction speeds and higher fees charged per transaction because of a substantial increase in users.

Bitcoin, in its current form, can handle around 7 transactions per second (TPS). Ethereum, which businesses are often more interested in as it can run smart contracts, can manage about 20 TPS. These are unacceptably low throughputs for most business applications (TSS, 2018). Scalability concerns must be effectively addressed before the Blockchain can be adopted on a wide scale, outside of cryptocurrency transactions that exchange very limited amounts of information.

7.2.2 Standardisation and interoperability

One of the major issues with the development of Blockchains is the lack of standardisation. There are hundreds, if not thousands, of Blockchain projects underway today. According to the Department of Homeland Security in the United States, there is an increasing diversification of Blockchain projects covering supply chain management, fintech, Internet of Things, and identity management. However, many of these are unable to communicate with each other directly (Department of Homeland Security, 2018, p.13).

Interoperability is a key requirement for Blockchain. Ecosystems that use Blockchain technology consist of a set of distributed nodes where immutable transactions are replicated. However, there are a growing number of different ledger technologies and there is no standard approach or plan to ensure interoperability (GS1, 2018, p.5). Ramesh Gopinath, Vice President, Blockchain Solutions and Research from IBM, argues that interoperability between Blockchain ecosystems will demand a solid foundation built on:

- globally unique, persistent identification

for organisations, locations and things.

- a standardised language for supply chain events.
- a scalable network governance model that crosses ecosystems. (Ibid, p.3)

The other issue often cited as a barrier to the adoption of Blockchain is the lack of standards dedicated to Blockchain. However, there is a process currently underway to create a suite of Blockchain Standards. Australia is managing the Secretariat of the International Technical Committee for Blockchain Standards (ISO/TC 307).

Ultimately, Blockchain needs international standards that are compatible with regulations and controls to ensure market confidence and consistency in the use of the technology. The standards focus on technical solutions that promote interoperability and compatibility between existing systems (Standards Australia, 2018, pp.2-4). These standards are still under development and it would be advisable to wait until they are developed before any work is done to apply Blockchain technology in the construction industry.

7.2.3 Governance: permissions and participation

The issue of governance, permissions, and participation in the Blockchain is a critical one. Generally, governance is about decisions that ultimately affect people ('stakeholders'). It is about the processes that participants in governance use to make decisions. It is also about how they coordinate the decisions and decision-making processes. It includes the establishment, maintenance, and revocation of the legitimacy of decisions, decision-making processes, norms, and other mechanisms for coordination (Zamfir, 2018). There are a series of questions to be satisfied prior to the building and creation of the Blockchain:

1. Who can participate in and access a ledger?
2. Who can write and share information on the ledger?
3. What rules govern data access, sharing, and ownership between members of one ecosystem to members of another, as well as supply chain participants who may not participate in any Blockchain ecosystem (e.g. consumers and regulatory bodies)?
4. How will privacy and the data security between members and non-members be managed?
5. What data is stored on-chain versus off-chain?
6. How is data on the ledger stored? Plain text or hashed?
7. What security mechanisms are required? (GS1, 2018, p.5)

These are critical questions, and there are currently no right or wrong answers. Every Blockchain project will have different outcomes and requirements. The complexity of this problem was evidenced in the pharmaceutical case study outlined earlier in this report.
Governance decisions matter, because ultimately, they influence how Blockchains work, how they are used, and what kind of communities develop around them.

7.3 Implementing Blockchain – what are the success factors?

Implementations of data sharing solutions that leverage Blockchain technology are arguably more complex than implementations based on more traditional data sharing technologies. Those evaluating this technology for implementing a data sharing solution should be aware that existing business processes will need to be reviewed, and often reworked, to realise the desired operational efficiencies. Because of this need to get the foundation right, the costs associated with an implementation may be difficult to gauge at the start of a project. According to Robert Beideman, Chief Solutions and Innovations Officer at GS1 Global Office, successful implementations of Blockchain require the following:

1. Clearly define the data sharing problems that need to be addressed.
   Companies looking to evaluate Blockchain technology should identify underlying business problems and what the desired solution to those problems may involve. Understanding the potential technology advantages of a Blockchain ledger solution to the business problems can then be examined. This activity is an important first step when considering a Blockchain ledger as a component to an overall solution, as it's quite possible that the business challenge may not require a ledger-based solution.

2. Identify the data required to meet the business objectives.
   Is the data accessible, of high quality and being recorded today? Poor quality data that is written to a ledger is simply a record of bad data. Additionally, what is written to the Blockchain is not rich data that may be acted upon to solve a business problem, but rather an immutable record that something occurred at a specific time, by a particular party. Rich data that can be acted upon is data stored and shared via business applications off-chain. All of this is dependent upon business processes being adapted to capture data of things that occur in the supply chain.

3. Consider the existing data sharing business processes and assess the changes needed to use Blockchain ledger technology.

   Understand what process changes are specific to capturing data to solve a business problem and what are specific to Blockchain.

   This exercise is important for sharing beyond one up/one down, as well as with immediate trading partners.

4. Understand the real benefits of Blockchain, including immutability of data, importance of maintaining a sequence of events and distributed control of data, and determine if these are absolute requirements for data sharing to solve the business problem.

5. Identify the necessary trading partner governance strategy for the ecosystem that an organisation is participating in. Consider the impact of existing governance rules within other Blockchain ecosystems that you'll need to interoperate with (GS1, 2018, p.6).

The EU Blockchain Forum believes that there are several success factors required for large-scale Blockchain projects. These include:

- Clear purpose and concept
  This is the most important factor. It is not technical, but conceptual. Projects

need to be clear about the goals they are trying to achieve. Without a strong vision and purpose, they risk failing.

- Governance
  This is challenging as the question of governance in collaborative consortia for decentralised technologies is relatively new. In a permission based Blockchain, the most important element of governance is identity.
- Component-based, service-oriented architecture
  It needs to be remembered that Blockchain forms only a small part of the overall architecture. What is stored off-chain is also important. Most of the data will be stored off the chain, so the project will need a shared, but encrypted and access-controlled, data repository.
- Homogeneous production environment and pooled resources A centralised, shared IT platform is required for the project. This develops common practices and tools for the consortium. (EU Blockchain Forum, 2019, pp.14-16).

Blockchain is still in the concept and exploratory stage in the construction sector, and Hultgren and Pajala argue that there are several consequences in using Blockchain:

- The market will be affected, depending on who owns the Blockchain system.
- The administrative work to review certificates can be simplified.
- The Blockchain technology cannot verify that all data entered is correct.
- Possibility to combine different supply chains for various materials improves.
- Various materials will have different outcomes due to supply risk and profit impact.
- The Blockchain technology will remain an idea in the construction industry unless it is anchored through pilot studies (Hultgren and Pajala, 2018. P.47).

These are pertinent points. The technology still has some distance to travel on the road to maturity, as evidenced in the Gartner Hype Cycle below. One important consideration that Hultgren and Pajala outline is the fact that even if Blockchain can deliver on everything that it promises, Blockchain is unable to discern whether information placed on the Blockchain is accurate. This does not account for human error or whether data placed on the Blockchain is falsified (Hultgren and Pajala, 2018, p.43).

7.4 Availability of product assurance data

We have focused on the potential of Blockchain to store and exchange product assurance and certification information. But even more fundamental for effective product assurance evaluation, regardless of the technology choice, is the availability and standardisation of product assurance data.

The is not just availability of standardised information at a single point, but rather widely across logistic supply chains. Information sources vary enormously including:

- Certification and accreditation authorities
- Manufacturers

- Retailers
- Band owners and suppliers
- Construction companies
- Transport companies

All the above parties may add information relevant to ensuring traceability and authenticity into supply chain data sharing systems. Coordinated action is a problem and while Blockchain promises a ledger for all to participate in, agreement is still needed what the data is and associated quality issues.

Certification and Accreditation Administration of the Peoples Republic of China

Certification bodies are an important part of the construction industry product supply chain. As covered earlier in the report they support product assurance through the issuing of certifications. One of the most important building product chains involves imports from China. However, certification certificates might not be current or could even be forged. In an ideal Blockchain world, certification information would be held on Blockchain or linked into product certification bodies. So, we talked to the Department of Certification (the Department) in China.

Department of Certification
The Department of Certification (the Department) is responsible for oversight of China's Compulsory Certification mark (CCC). This certification is widely used on many electrical, industrial, and construction products.

Potential use of Blockchain
The Department is in the early stages of researching whether there may be value in the use of Blockchain in certification processes and maintaining certification data.
They are not aware of any use of Blockchain to trace and authenticate building and construction products in China. Nor are they aware of businesses using Blockchain to store CCC mark certificates or associated certification information, or to exchange this information with other businesses in China.

Authentication of CCC mark
Like other Accreditation and Certifications systems around the world, CCC certificates are identified with unique number sequences. These can be searched on the Department's website or via Certification Bodies (Accredited by the Department) to ensure currency of certificates. Once found, technical product assurance information associated with certificate is attached and downloadable.

While in theory Blockchain could provide greater supply chain quality assurance, and security of certification information, the Department has no plans in the foreseeable future to replace existing systems with Blockchain.

7.4.1 Data quality and consistency

There is fragmented data availability across the New Zealand construction sector. Often product data exists publicly on supplier websites but that data can be out-of-date or unavailable. One interviewee discussed this very issue and stated:

> "We rely on suppliers' websites for up-to-date technical information on the product in question. This is because the onus is on the supplier to keep the information updated. Suppliers have a wide variety of information available on their website. Some of it is good and some not so good. Material Safety Data Sheets need to be available for each product. However, there is a lack of clarity and standardisation of what information is required per product."

Much is made of the fact that Blockchains are tamper-proof, and that once data is added to the Blockchain it can't be changed. And in principal one could lock-down the original data source in a weblink. While this ability helps to prevent fraudulent tampering of the ledger, it cannot prevent false information being fed into the ledger in the first place (Ganne, 2018, p.6). This data quality issue affects all information sharing technologies, not just Blockchain.

7.4.2 Existing catalogues of product information

There are currently several databases in operation that hold relevant information related to product assurance and compliance in New Zealand. These include:

- Supplier and manufacture web-sites as discussed
- Retailer websites
- Code Mark
- Masterspec: MiProducts
- GS1 New Zealand's National Product Catalogue (NPC)
- EBOSS Product Catalogue

There is no consistency in how products are uniquely identified, or the kind of basic information attributes presented that maybe relevant to product assurance needs. This lack of standardisation means information cannot be shared between the databases or made easily available to industry participants. Many suppliers will carry the costs of having to make multiple listing of products across sites and the hassle of updating multiple sites when product attributes and assurance information changes.

The current review into building products and methods proposes to require manufacturers and suppliers (including importers) to supply publicly accessible information about their building products. This information includes:

- description of the product, including a globally unique identifiable code
- details of the manufacturer/supplier, including contact details
- scope and limitations of the product's use
- design and installation requirements

- maintenance requirements
- Certification and Accreditation Administration of
- the Peoples Republic of China
- a declaration if a product is subject to a warning or ban (MBIE, 2019).

A standardised set of agreed product information is critical to improving information and accountability for building products and methods.
In October 2018, buildingSMART International (BSI) and GS1 signed a Memorandum of Understanding to enable the construction industry to benefit from the combined expertise of both organisations through the use of standards and services they deliver. The use of global buildingSMART and GS1 standards, in particular for product identification and exchange of product data, is critical in addressing today's challenges of digitalisation in the construction sector. Without standardised forms of product identification and information it is hard to see how effective sharing of product information can take place of various business information exchange processes be automated.

7.5 Where is Blockchain on the Hype Cycle?

The Hype Cycle is a branded graphical presentation developed and used by the American research, advisory, and information technology firm Gartner to represent the maturity, adoption, and social application of specific technologies.

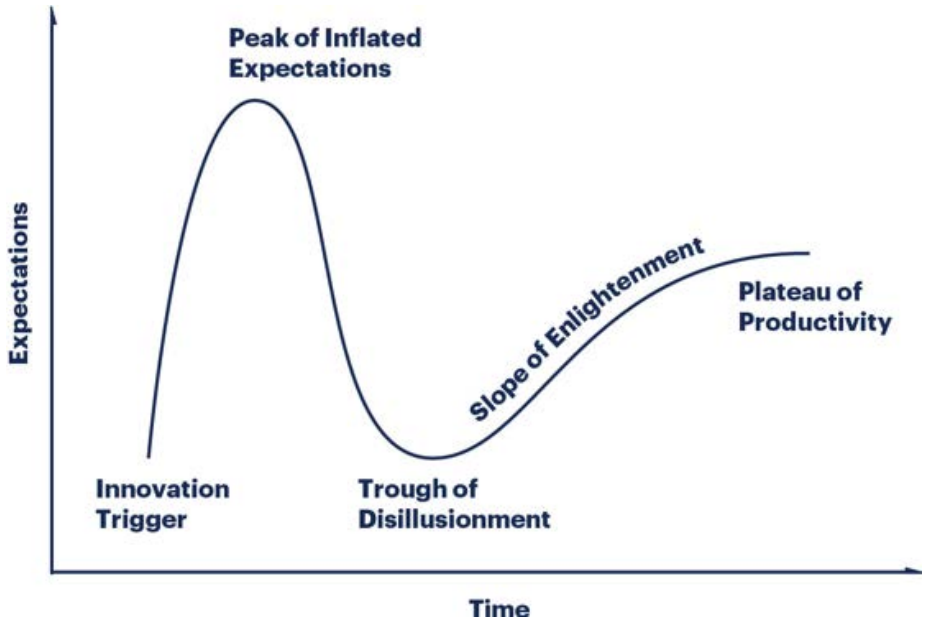


Figure 7-1 - Gartner Hype Cycle

Source: Gartner Hype Cycle, https://www.gartner.com/en/research/methodologies/gartner-hype-cycle.

There are five phases in the Hype Cycle:

1. **Innovation Trigger**
   A potential technology breakthrough kicks things off.
2. **Peak of Inflated Expectations**
   Early publicity produces several success stories – often accompanied by scores of failures.
3. **Trough of Disillusionment**
   Interest wanes as experiments and implementations fail to deliver.
4. **Slope of Enlightenment**
   More instances of how the technology can benefit the enterprise start to crystallise and become more widely understood.
5. **Plateau of Productivity**
   Mainstream adoption starts to take off. Criteria for assessing provider viability are more clearly defined.

Gartner's review of the Hype Cycle for Emerging Technologies places Blockchain on the cusp of the Trough of Disillusionment and states that the Plateau of Productivity for the technology will occur in 5-10 years.

While there is a lot of hype about the potential of Blockchain, only 1% of Chief Information Officers (CIOs) have any kind of Blockchain adoption within their organisations, and only 8% of CIOs were in short-term planning or active experimentation with Blockchain, according to Gartner's 2018 CIO Survey. According to the new research, 77% of CIOs surveyed said their organisation has no interest in the technology and/or no action planned to investigate or develop it.

This backs up our assessment that key developments with the technology need to take place, including the development of standards to ensure the technology is interoperable.

To date, optimists of Blockchain have been driving the cycle, pushing hype towards an early Peak of Inflated Expectations. As their overly hopeful predictions fail to eventuate, the pessimists dominate, pushing hype back towards the Trough of Disillusionment. Surviving technologies slowly climb back out (Heatley, New Zealand Productivity Commission, 2019). Ultimately technology won't develop without optimists. New ideas need research funding and seed capital. And attracting money in noisy, competitive environments requires a relentlessly positive message.

However, technology needs pessimists too. They put a brake on the exuberance of optimists and help kill off some ideas. They identify the social harms overlooked or downplayed by optimists. Pessimists jump enthusiastically on optimistic predictions that fail to eventuate, asking optimists to explain themselves (Ibid).

Until we reach the Plateau of Productivity, it is advisable for the construction sector to keep a watching brief on the evolution of Blockchain technology.

7.6 Implications for the construction sector

When conducting interviews about the use of Blockchain in the construction sector, there was very little knowledge of how Blockchain works from a practical level. Those who were familiar with Blockchain were sceptical about its potential use. One interviewee stated:

Blockchain technology is not something which is able to solve a problem which other technologies can't solve. One has to take an economic view of what is the most robust solution. The other point I would like to mention here is around realising the real value out of the outcomes we are looking at e.g. provenance or product assurance. It's not just Blockchain in isolation, it's a combination of technologies that are required. For example, it might be IOT (Internet of Things) and Blockchain required, which would eventually deliver a solution which provides the value that it should provide.

Blockchain should not be seen or viewed in isolation. It should be seen as part of the overall solution.

The construction industry can improve immensely when it comes to digitisation. Research indicates that construction coordination is most of the time managed by telephone, mail, and paper documentation (Hultgren and Pajala, 2018. p.10). An important part of the supply chain in the construction sector is focused at the product level – ensuring quality checks take place to determine that the product in question is fit for purpose. A level of quality assurance of products is required (Ibid, p.11).

In the construction industry in New Zealand, and for the nature of this research, any application of Blockchain technology for product assurance and compliance should be on a permission-based Blockchain. The reason for this is that there must be a trusted authority overseeing any Blockchain. The regulator is that authority in New Zealand. However, without standardised information requirements that show a product complies with the Building Code, neither the Blockchain solution nor indeed any other technology, is the answer.

One interviewee who is familiar with Blockchain technology and wider technologies for business stated:

> "I have not come across any scenario or application at this point in time, (my interest has been in three areas – supply networks, asset management and manufacturing where I have a reasonable amount of experience and knowledge with Blockchain) that Blockchain is able to solve that existing technologies are unable to solve.
> As we say the public Blockchain and the Blockchain that is controlled by an ecosystem (permissioned or consortium), I don't think at this point in time we have reached a point of maturity where public Blockchains would start solving some of the problems which it is meant to solve. I know a lot of trials have happened at an industry level, but it is at the enterprise ecosystem that Blockchain has a role.

Again, this view is consistent with other expert views on the current state of Blockchain technology. The same

interviewee goes on to comment that there is too much time being focused on the technology and being caught up in the hype:

> “What I see now is that there is too much time spent by people on the technology application of Blockchain. Not enough thought has been placed on regulation, around building ecosystems, getting those minimal criteria to build those ecosystems, and also on the reliability of the source data that is added to the Blockchain. You might be talking about trust, but if the source data is flawed, then it will flow through the Blockchain. Those issues require more attention, and that attention is coming. Data orchestration technology may be a key enabler for this.

Numerous thought pieces on Blockchain and its technology highlight that setting up a Blockchain requires significant investment and coordination, as well as substantial changes to existing systems and culture (Ganne, 2018, p.111). This will certainly apply in the construction sector, which is already grappling with a range of issues in a complex and ever-changing ecosystem. The challenge of adding another system to existing obligations will add more work to an already heavily-burdened sector.

There is scope for further research that focuses on how the existing databases outlined above can work together to supply core product information that is easily accessible and usable throughout the industry. The potential exists, through a coordinated approach for the entire construction ecosystem to be able to access this information.

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Appendix 1: List of interviewees

While undertaking this research the following people were interviewed as part of the process. Quotes used throughout the research have been anonymised to protect the interviewee.

- Bruce Kohn – Chief Executive, Building Industry Federation
- Bryan Martin – Chief Executive, Effective Homes Ltd
- Edmond Gomes – Supply Chain and Logistics Manager, Independent Building Proucts
- Jane Reid – Merchandise Manager, PlaceMakers
- Jeremy Strongman –Consenting Officer, Wellington City Council
- John Gardiner – Director, Building Confidence Ltd
- Kevin MacDonald – Manager Master Data, Mitre 10
- Dr Mark Harrison – Technical Research Specialist, Information Management Systems including Blockchain
- Mark Singh – Head of Advisory and Digital Strategy, Syd Consulting
- Peter Thorby – Director, Tekton Consulting
- Robert Beideman – Chief Solutions and Innovation Officer, GS1 Global
- Semanie Cato – Head of Sales and Partnerships, Centrality
- Stephan Lam – Chief Operating Officer, GS1 Hong Kong

Appendix 2: World Economic Forum – key question analysis

Question A states that for a Blockchain to be an appropriate solution, the business context needs to be understood. The questions ask whether or not the problem requires the removal of an intermediary (World Economic Forum, 2018, p.7). In the case of product compliance and assurance, the use of Blockchain is not trying to remove any intermediaries. Ultimately the supplier of the product needs to provide evidence that it is fit for purpose. That evidence needs to be supplied so that those in the construction sector and regulators can have confidence that the product is fit for purpose.

Question B states that for Blockchain to be successfully applied, it needs to be working with ‘‘digitally native assets’, meaning assets that can be successfully represented in a digital format (Ibid). This is possible for a building product that has a GTIN (Global Trade Item Number). This is a globally unique identifier that can be used to provide a digital formal for a physical item.

Question C is focused on whether a permanent record can be created for the digital asset. This is one of the critical questions, as one of the strengths of Blockchain is the concept that it is the source of trust (Ibid). In this sense it is the supplier of the product who needs to ensure that the product is fit for purpose. The question here is whether a permanent record is required, as products evolve over time and updated evidence is provided by the supplier.

Question D is concerned with the speed required for the business process in question. Currently Blockchains are unable to handle transactions at high speed. Scalability of Blockchain is one of the most cited issues with the current state of the technology.

Question E states that it is not currently advisable to store non-transactional data on a Blockchain (Ibid). Non-transactional data has a starting date and an ending date that define when the condition or data value remains unchanged. This is crucial when it comes to issues on product assurance and compliance. If a product’s performance or specifications are adapted or changed then new evidence that the product is fit for purpose is required.

Question F asks whether the problem needs to rely on a trusted party? Examples of this would be for compliance or liability reasons (Ibid). The World Economic Forum states that ”in use cases where regulation plays a big role, it may be necessary to include regulators in the project and deliver means by which the regulators can ensure compliance with laws. It could be quite difficult to deploy a Blockchain without regulatory engagement” (Ibid). This is critical as trust is required and suppliers of products need to provide evidence that their product is fit for purpose. Regulators have a role to play in the building standards framework and in this decision-tree model, Blockchain may work, but further research and development is required. In its current state Blockchain is not in a mature enough state to solve this.

Question G concerns whether the Blockchain is being used to manage contractual relationships or value exchanges (Ibid). For the purpose of this research, contractual relationships are not being managed. The idea is whether Blockchain can be used to provide a mechanism where a product is compliant with regulations.

Question H is focused on whether all members of the network need to be able to write transactions to the Blockchain (Ibid). There are many manufacturers suppling products into the

New Zealand market. A requirement would be for those suppliers to be able to add information to the Blockchain.

Question I asks whether contributors know and trust each other (Ibid). If trust is already established, then there is probably no need for Blockchain. In the case of the construction industry, many suppliers are already known, however there is no requirement that they actually know each other.

Question J is focused on whether functionality control is required (Ibid). If functionality control is required, then there is a strong case for a permissioned Blockchain.
Question K asks whether or not transactions should be public (Ibid). If the transactions can be made public, then the World Economic Forum states there is a strong case for a public Blockchain.
The decision tree concludes that Blockchain technology may be most appropriate when:

- there is a desire to remove intermediaries or brokers
- working with digital assets (or digital representations of physical assets)
- permanent authoritative records can be created for the digital asset.

Appendix 3: CodeMark Certification Information

Product Certification: CodeMark

CodeMark is a voluntary product certification scheme that provides information to show a building product meets the requirements of the New Zealand Building Code. CodeMark was developed in conjunction with the Australian Building Codes Board (ABCB) as the trans-Tasman building products market has become increasingly integrated. The scheme operates in both Australia and New Zealand in accordance with the CodeMark Scheme Rules. JAS-ANZ (the Joint Accreditation System of Australia and New Zealand) has been appointed by MBIE and the ABCB as the body responsible for assessing and accrediting product certification bodies. (MBIE, 2018).

Once a product is ready to be assessed then a product certification body needs to evaluate the application. Currently there are six accredited certification bodies for New Zealand. Those bodies are:

- AsureQuality
- BRANZ
- Bureau Veritas
- CertMark International Pty Ltd
- GlobalMark Pty Ltd
- SAI Global

The Building Act 2004 and the Building (Product Certification) Regulations 2008 provide the legislative basis for the CodeMark scheme in New Zealand. The regulations prescribe the:

- criteria and standards for accreditation as a product certification body including the fees payable to the accreditation boy
- criteria and standards for certification of products
- minimum content for product certificates.

Accredited product certification bodies are the only companies who can evaluate products for CodeMark and issue CodeMark certificates. They must follow the CodeMark Scheme Rules when doing so.

When applying for a CodeMark certificate the following information is required with the application:

- a description of your product
- its purpose and use (for example, the type of buildings it can be used in)
- any limitations or conditions on its use
- all clauses of the Building Code that you want the certification to cover
- technical details

- details of how your product is to be installed
- product support and maintenance requirements (MBIE, 2018).

According to the MBIE website a product technical statement (PTS) is recommended. A PTS summarises the key details about the building product or system. It does not replace actual evidence of compliance, but it is a statement about the product. A PTS should include the following information:

- a description of your product (including a unique identifier to make sure different users are talking about the same product) and its intended use
- details of the manufacturer (if issued by a supplier)
- date of issue (or revision) and relevant links so users can confirm they have the latest version
- purpose and use:
    - a statement of where and how your product can be used, employing recognised New Zealand terms (such as high wind, seismic and corrosion zones) and types of buildings (for example, within the scope of NZS 3604)
    - any limitations on that use
- any conditions on the use of the PTS
- a statement of the Building Code clauses relevant to your product and clear links to evidence to support your compliance claims (such as relevant test reports, technical opinions, product certification details or other supporting information)
- links to design, construction and installation instructions for designers to specify your product, and builders and tradespeople to install it
- links to maintenance requirements so the building owner can maintain your product effectively
- describe potential consequences of not carrying out specified maintenance
- contact details for technical support; ideally for New Zealand organisations that can provide product advice and assistance (Ibid).

In preparation for certification, the following information about the product is also required:

- details on how you believe your product or method complies with the Building Code (is it an Acceptable Solution, Verification Method or alternative solution)
- evidence of compliance with the Building Code (such as test reports, in service history, independent assessments and/or appraisals)
- a product quality plan: this is document specifying which procedures and associated resources shall be applied to a specific product and its manufacture and must be compliant with ISO Standard 10005:2005 (AS/NZS 10005:2006)

CERTIFICATE OF CONFORMITY

This is to certify that

Alpolic/fr®

CertMark International

CODEMARK™

Complies with the New Zealand Building Code:

1. B1.3.1 and B1.3.2 - Structure
2. B2.3.1(b) - Durability
3. C3.4(a) - Fire
4. E2.3.2, E2.3.3 and E2.3.5 - External Moisture
5. F2.3.1 - Hazardous Building Materials

Product Description

Alpolic/fr® is a 4mm thick Aluminum Composite Material (ACM) comprising two skins of aluminium, sandwiching a proprietary core used for cladding of buildings.

Refer A1 below.

Product Purpose or Use

The Alpolic/fr® is used as a cladding used on exteriors of buildings and may also be used as an interior lining.

Subject to the following Conditions & Limitations:

a. Alpolic/fr® must only be installed in accordance with the PSP Technical Manual October 31, 2018.
b. No claim for compliance is made for any clause not listed above and is subsequently outside the scope of this certification.
c. The compliance requirements of the wall, to which the cladding is attached to, is outside the scope of this certification.
d. For further information about specific installation details contact the Certificate Holder.
e. Nothing in this document should be construed as a warranty or guarantee by CMI, and the only applicable warranties or guarantee will be those provided by the Certificate Holder.
f. The Certificate Holder must maintain compliance with the conditions set out in Regulation 15 of the Building (Product Certification) Regulations 2008.

Certificate Holder

PSP Limited
NZBN: 9429038193958
320 Rosedale Road,
Albany Auckland, New Zealand
Ph: +64 9 415 2800
W: www.psp.co.nz

Certification Body

CertMark International Pty Ltd
ABN: 80 111 217 568
JAS-ANZ Accreditation No. Z4450210AK
PO Box 321 Tuakau 2121
+64 (09) 951 8246
www.CertMark.org

John Thorpe
CertMark International Pty Ltd

15/11/2018
Date of Issue

CM40246-I01-R00
Certificate Number
Formerly issued as CM40075

- This certificate is issued by an independent certification body accredited by the product certification accreditation body appointed by the Chief Executive of the Ministry of Business, Innovation & Employment (MBIE) under the Building Act 2004. MBIE does not in any way warrant, guarantee, or represent that the building method or product the subject of this certificate conforms to the New Zealand Building Code, nor accept any liability arising out of the use of the building method or product. MBIE disclaims, to the extent permitted by law, all liability (including negligence) for claims of losses, expenses, damages, and costs arising as a result of the use of the building method(s) or product(s) referred to in this certificate
- It is advised to check that this Certificate of Conformity is currently valid and not withdrawn, suspended or superseded by a later issue by referring to the MBIE website, www.mbie.govt.nz
- This certificate may only be reproduced in its entirety.

A1 Product Specifications

Panel Dimensions		
Thickness:	4mm	
Panel Width (tolerance ±2.0 mm):	95mm, 1270mm, 1575mm	
Length (tolerance ±4.0mm):	<7200mm	
Surface finish layer:	Fluoropolymer coating, solid content 50g/m²	
Surface and backside skin:	Aluminium alloy, thickness 0.5mm, weight 1.35kg/m²	
Core material Composition (weight %):	Polyethylene containing aluminium hydroxide thickness 3.0mm, weight 4.89kg/m²	
	Aluminium hydroxide	70%
	Polyethylene	28%
	Organic additives (fatty acid type)	2%
Backside Protective layer:	Polyester coating, solid content 8g/m²	

Classification		Unit	
Physical Properties	Specific gravity	-	1.90
	Bow tolerance	-	±0.5% of the length and/or width
	Squareness tolerance	mm	Maximum 5.0
	Weight	Kg/m²	7.6
	Thermal expansion	10^{-6}/°0	24
	Thermal conductivity	W/m-K	0.45
	Deflection temperature	°C	116
Mechanical Properties of Composite Metal	Tensile strength	Mpa, N/mm²	49
	0.2% proof stress	Mpa, N/mm²	44
	Elongation	%	5
	Flexural elasticity	Gpa, kN/mm²	39.8
Sound Transmission Loss		STC	27
Metal Thickness with Equivalent Rigidity			Aluminium 3.3mm

A2 Installation Requirements

Alpolic/fr® must be installed in accordance with the PSP Technical Manual October 31, 2018.

A3 Other Relevant Technical Data

When designed, used, installed and maintained in accordance with the PSP Technical Manual October 31, 2018 Alpolic/fr® will meet the following provisions of the NZBC:

B1.3.1 and B1.3.2	Alpolic/fr® conforms to the requirements of AS/NZS 4040:1996 and AS/NZS 1170:2011 structural design as applicable to wall cladding systems.
B2.3.1(b)	Regular maintenance in accordance with the manufacturer's recommendations http://www.alpolic.com/alpolic-intl/tech_maintenance.html is essential to ensure the performance requirements of the NZBC are met and to ensure the maximum serviceability of Alpolic/fr®. An inspection of Alpolic/fr® installations should be undertaken at least annually to determine the conditions of the whole building. Items to be checked include, but are not limited to: • Dirt – any accumulation of dirt should be washed from the surface of the panels; • Scratches and dents – these need to be identified and repaired; and

- This certificate is issued by an independent certification body accredited by the product certification accreditation body appointed by the Chief Executive of the Ministry of Business, Innovation & Employment (MBIE) under the Building Act 2004. MBIE does not in any way warrant, guarantee, or represent that the building method or product the subject of this certificate conforms to the New Zealand Building Code, nor accept any liability arising out of the use of the building method or product. MBIE disclaims, to the extent permitted by law, all liability (including negligence) for claims of losses, expenses, damages, and costs arising as a result of the use of the building method(s) or product(s) referred to in this certificate
- It is advised to check that this Certificate of Conformity is currently valid and not withdrawn, suspended or superseded by a later issue by referring to the MBIE website, www.mbie.govt.nz
- This certificate may only be reproduced in its entirety.

	• Joint sealant – identify any failures and repair. Minimum ground clearance as set out in PSP Technical Manual October 31, 2018 must be maintained at all times during the life of the Product to maintain the durability and weather tightness of the installation. Manufacturers Warranty: • The manufacturer of the ALPOLIC®/fr panels provides a minimum of 15 years warranty (from date of completion) when the panel is closer than 1 km from the ocean. • The manufacturer of the ALPOLIC®/fr ACM panels provides a minimum of 20 years warranty (from date of completion) when the panel is further than 1 km from the ocean. • PSP Limited warrant ALPOLIC®/fr for not less than 15 years provided it is installed in accordance with the most current PSP Technical Manual 31st October 2018.
C3.4(a)	When tested in accordance with ISO 9705:1993 Alpolic/fr® achieves a Material Group Number 1.
E2.3.2, E2.3.3 and E2.3.5	Alpolic/fr® has passed the requirements of AS/NZS 4284:2008. The cavity must be sealed off from the roof and subfloor space in order to meet the performance requirement of E2.3.5.
F2.3.1	Audit of the supplied Material Safety Data Sheet as well as history in service has determined that the product does not give rise to harmful concentrations of any gas, liquid radiation or solid particles at the surface of the material where the material is exposed, or in the atmosphere of any space and is therefore not a health risk to people.

B1 Basis of CodeMark Certification

Alpolic/fr® product has been evaluated in accordance with the requirements of the Building (Product Certification) Regulations 2008 Clause 8. CMI has followed procedures for certifying Alpolic/fr® that are based on evidence established by:

- Testing of Alpolic/fr® at accredited testing facilities;
- Assessing a quality plan for Alpolic/fr® which conforms to ISO 10005:2018 and the CodeMark scheme rules version 2009:1;
- By reviewing testing of, samples supplied to ascertain whether or not the product meets the performance requirements specified on this certificate; and
- Conducting site audits of the factory to verify compliance of Alpolic/fr® with the agreed Scheme of Testing and Inspection (STI).

B2 Sources of Information

- Testing to ISO 9705:1993. Fire tests—Full-scale room test for surface products.
- Testing to AS/NZS 4284:2008. Testing of building facades.
- Testing to AS/NZS 4040:1996. Methods of testing sheet roof and wall cladding Resistance to impact.
- Testing to AS/NZS 1170:2011. Structural design actions.
- Testing Material Investigation Report Indicative Flammability Potential, Composition and Toxicity Screening of Exterior Cladding Systems.

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