External Research Report ER62 [2021]

# Chip of the new block(chain): blockchain and the construction sector

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Project LR10482

University of Auckland, funded by the Building Research Levy

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Funded from the
Building Research Levy


ISSN : 2423-0839

Cover page photo credit: Dermott McMeel

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# acknowledgements.

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BRANZ
Funded from the Building Research Levy

THE UNIVERSITY OF AUCKLAND
Te Whare Wānanga o Tāmaki Makaurau
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# contents.

# executive summary.

Blockchain has been around since 2008, and although it is surrounded by a lot of hype it also demands to be taken seriously. It is no longer simply associated with 'fringe' behaviour, such as Bitcoin and other cryptocurrencies. The United Nations World Food Programme and IBM are both using blockchain. Bermuda and Malta have created regulatory environments to encourage innovation in blockchain. In summary blockchain is not going away, and sooner or later it will impact the construction industry.

This report is the summary of a two-year research programme exploring what blockchain means for the construction sector. It starts by explaining blockchain and looking briefly at some of the challenges currently facing construction. The construction sector is often criticised for under-performing relative to other sectors in metrics such as waste reduction, productivity and modernising processes. The report goes on to describe how we undertook the research, including industry workshops to help understand blockchain and create future scenarios where blockchain could begin to solve some of the challenges facing construction. This research was funded by the Building Research Association of New Zealand (BRANZ) and was led by Dr Dermott McMeel and Associate Professor Alex Sims. Dermott has a background in architecture and is a Senior Lecturer in Design and Digital Media as well as Head of Department for Creative Technologies. Alex has a background in corporate law and is an expert on legal issues surrounding blockchain and smart contracts. This leadership has enabled this programme of research to look deeply into construction processes and draw out ideas, future concepts and clear opportunities for this transformative new technology.

While the report recognises that blockchain technology is still in its infancy, it also recognises that there are some features which present opportunities to the sector. In a collaboration between industry stakeholders and researchers over the last two years we have identified potential areas where blockchain is most likely to be applicable. We have also developed detailed use-cases where it is possible to get a deeper understanding of what some of these changes might start to mean. Finally, we have a resource section for those interested in learning more about blockchain.

This report focuses on three use-cases of blockchain that emerged in our workshops and received sustained interest from stakeholders over the two years as their viability and potential was researched further. These uses-cases involve the application of blockchain to:

- A Token economy for trading construction waste.

Token economies make it easier to promote and incentivise trade in specific areas. Construction waste is a major problem for construction, much of which ends up in landfill. This use-case looks at how blockchain could make it possible to create a sophisticated economy around trading in construction waste by creating financial incentives to manage and reuse it.

- Smart contracts for payment.

Late and contested payments are significant causes of conflict in the sector. Smart contracts are digital contracts which can be programmed to execute certain clauses automatically. Payments can be triggered automatically when a contract is verified as completed, speeding up the process. We look at what a smart contract system might look like within a construction project.

- Smart contracts for material procurement.

Material procurement also emerged as a complicated, paper-based process. As such is it prone to allowing mistakes in orders to go unseen. The research looked at how smart contracts could simplify, stream-line and provide a much clearer management overview of procurement processes.

The research generated additional wide-ranging ideas that are not covered here, such as: a token economy to support local community development; a concept for an on-demand 'uber for material logistics'; and an idea around how we might use these new technologies to consider and include the natural environment when we are making the built environment. This is not an exhaustive list of opportunities; however, we have chosen to focus the report on material directly relevant to the construction sector. Finally, although blockchain is an emerging and transforming technology it is a mistake to adopt the 'let's wait for it to mature' frame of mind. Blockchain is already being used or trialled by sectors and groups considered risk averse. We hope you find this report useful and we hope it prompts you to learn more about blockchain and think about what it means for your organisation.

Dermott & Alex

# introduction.

Blockchain is a burgeoning area of research, and there is much speculation how it might be applied to the architecture, engineering and construction sector. This research programme has its origins in 2018-2019 BRANZ Building Research Levy Prospectus which invited proposals to address 'the potential of blockchain – information management in the New Zealand construction industry.'

Researchers compare the emergence of blockchain to the emergence of the internet. When it was emerging we wondered what it was, now we cannot imagine living without it. Blockchain, sometimes referred to more generally as digital ledger technology (DLT) is the most recent in a series of developments that constitute the evolution of the twentieth century economic model to the twenty-first. A large part of which has been implementing digital technologies that have been couched in terms such as the Internet of Things, Industry 4.0, digital fabrication, digital twins and so on. This report summarises a research project that took place between 2018 and 2020 looking at the opportunities that blockchain and its associated technologies might offer the construction sector. This project was funded by BRANZ (the Building Research Association of New Zealand) and led by Dr Dermott McMeel and Associate Professor Alex Sims from the University of Auckland. We report on our findings and focus on two specific aspects of blockchain—smart contracts and token economies—and how this might start to transform construction into a fairer, more efficient, more collaborative and greener industry.

> “ Researchers compare the emergence of blockchain to the emergence of the internet. ”

# what is blockchain?

Blockchain forms the foundation for a distributed system of organisation, which, at its heart, is an entirely new and completely different way of coordinating people and resources.

Transactions and agreements are stored in a distributed ledger of information that is decentralised and viewed by a designated group of users. The information, once published is unable to be changed which offers a greater amount of transparency with transactions.

Blockchain uses aspects of the underlying technology that supports Bitcoin, namely the distributed ledger technology (DLT) (Satoshi Nakamoto, 2009). The DLT can be viewed as a database shared with many interacting parties, however rather than having one source of information, such as the cloud system, here multiple 'ledgers' are accessed and updated simultaneously. This becomes a network where interaction and transactions are made in a peer-to-peer manner concurrently. Information exchanged and updated by multiple users is enabled by an entrenched network protocol established within the DLT framework. This central or single source of truth within the blockchain system becomes an immutable record of transactions and interactions which aids in transparency. These interactions are then updated and accessible by the multiple parties and require no intermediaries for approval as the protocol has been maintained by the network and blockchain. These transactions or 'blocks' within the blockchain are incontrovertible and a record that is transparent, traceable and resilient is created. This resilience is also highly resistant against hacking or attacks, since 2009, the inception of blockchain use.

# blockchain – a brief history.

Perhaps the easiest way of understanding blockchain is understanding its origins. In 2008 the world experienced an unprecedented global banking collapse. This was broadly as a result of banks taking undue risk combined with limited oversights within the banking system.

Centralised and decentralised systems, by their nature, have very few points within the system where an overview of that system can be seen. Consequently, there are very few opportunities to see and understand the 'big picture' within such a system. Bankers taking risks with mortgages or loans are rewarded if the risk pays off. This imbalance in risk and reward, in this context, provides few rationales not to take risks with people's money. This imbalance has been explained in greater detail by economist Yanis Varoufakis in 'Talking to my Daughter About the Economy' (Varoufakis, 2017).

Shortly after 2008, a person or persons using the alias Satoshi Nakamoto released a paper proposing a peer-to-peer digital cash system (Nakamoto, 2008). Transactions would be recorded publicly using digital ledger technology (DLT) removing the need for a third-party (a bank or bankers) to record and verify transactions. It, therefore, proposed the creation of a public banking system that did not require banks or bankers. This would facilitate significantly better oversight of the global state of transactions and remove the risk/reward imbalance by removing the need for banks and bankers acting as third-party mediators. The digital ledger technology (DLT) was blockchain and the digital cash was Bitcoin.


> “Centralised and decentralised systems, by their nature, have very few points within the system where an overview of that system can be seen. Consequently, there are very few opportunities to see and understand the 'big picture' within such a system.”

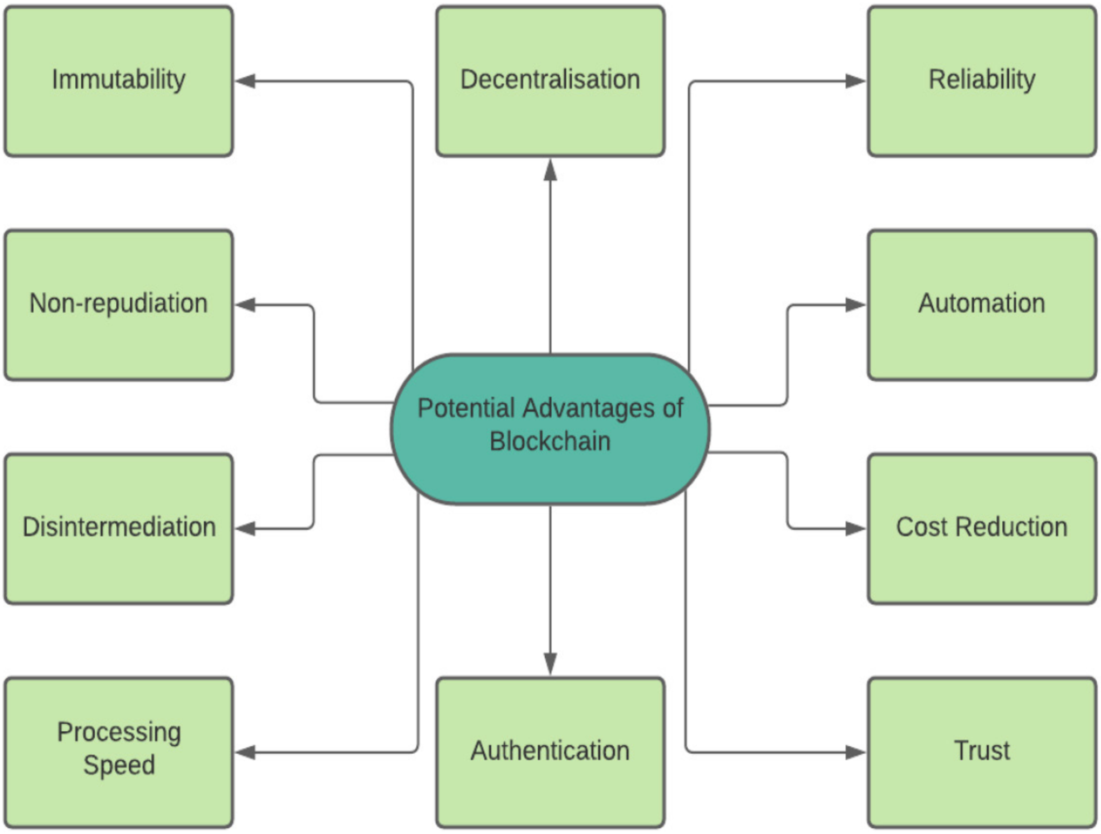



Figure 1:Advantages of Blockchain Technology Adapted from “Blockchain Research, Practice and Policy: Applications, Benefits, Limitations, Emerging Research Themes and Research Agenda” By Hughes et al., p.13.

- Decentralisation — Operating across a peer-to-peer network made up of computers (known as nodes).
- Immutability — Once blocks are chained, the data cannot be modified.
- Reliability — given that all nodes have an identical copy of the blockchain which is checked through an algorithm. The algorithm can identify any inconsistencies.
- Authentication — in blockchain, a Proof-of-Work mechanism is used to validate transactions and uses a mathematical and deterministic currency issuance mechanism to reward its miners.
- Disintermediation — Traditional centralised processes require human input to assure trust. However, since blockchain has trust built in by default, the number of intermediaries may reduce.
- Non-repudiation — Due to the integrity of the transaction history, the parties cannot dispute or deny their transactions on the blockchain.
- Automation — Interactions among parties may be automated through the working mechanism of blockchain, which may further reduce the overall human input.
- Processing speed — There may be significant increase in the execution speed, as intermediaries are removed, and more processes are automated.
- Cost reduction — In some case, the overall net cost in the long-run will

decrease, as the benefits gained from the removal of intermediaries and automated processes may outweigh the initial cost of capital combined with the on-going transaction costs.
- Trust — Trust is redefined by the principles of transparency and immutability in the blockchain technology.

In its simplest terms it addresses the two fundamental problems that caused the banking crisis of 2008. First, it solves the risk/reward power asymmetry inherent in a centralised or decentralised system; no bankers means no one person would benefit. Second, it creates a constant and updating 'world-view' of the entire ledger of transactions, enabling significantly more oversight. Indeed, computers on the Bitcoin network check for unauthorized attempts to alter transactional records. The importance cannot be over-stated, as virtually every human civilisation, every bank, council and local library is based on a centralised or decentralised organisational structure. Blockchain creates a technological platform to enable distributed organisational structure.

Blockchain has found most success by eliminating the need for de-centralised organisational structures. We can view limited oversight as a symptom of de-centralised organisational structures (Figure 2: sub-image 'B'). There are two salient features to such organisational structures. Firstly, as you move from the peripheral nodes to the central nodes each point of convergence only has a partial exposure to and overview of structure. In addition, for most de-centralised organisations to manage the flow of information it is distilled into reports or summaries at these points of convergence before being passed to a more central point. Abstracting the information as it flows corrupts the ability to obtain an accurate overview of the overall organisational system. The second feature of hierarchical de-centralised systems is power asymmetry between the nodes on the pathway that leads to centralised convergence, and those that do not. This results in most organisations having small powerful groups of people at these points of convergence involved in critical decision-making; where decision-making has the potential to unduly favour this small group.

Blockchain remains an abstract concept and hard for many to grasp. It is because we—as a civilization—have no real point of reference for what a distributed (Figure 1: sub-image 'C') system of organization would be. Most of our history has used centralised and decentralised techniques for organisation (Figure 2: sub-image 'A' and 'B'). However, Blockchain allows

“ Blockchain remains an abstract concept and hard for many to grasp. It is because we—as a civilization—have no real point of reference for what a distributed (Figure 1: sub-image 'C') system of organization would be. ”

for a shift away from a decentralised system to a distributed system. In both centralised and de-centralised organization systems things flow back to a central point or points which becomes a hierarchy or levels within these systems; people or groups with control and power over other people and groups. Blockchain provides a distributed structure for organisation (Figure 2: sub-image 'C'), whereby control and power is taken from a few key positions in the organisations and distributed more widely across the organisation. Furthermore, blockchain automatically creates a digital ledger technology DLT, or record. These records are incredibly difficult to alter, thus trust can be placed in them without the need for the 'trusted third-party' validator. The records become visible to all users the ledger of transactions at all times increasing transparency and the potential for a meaningful overview of the system.



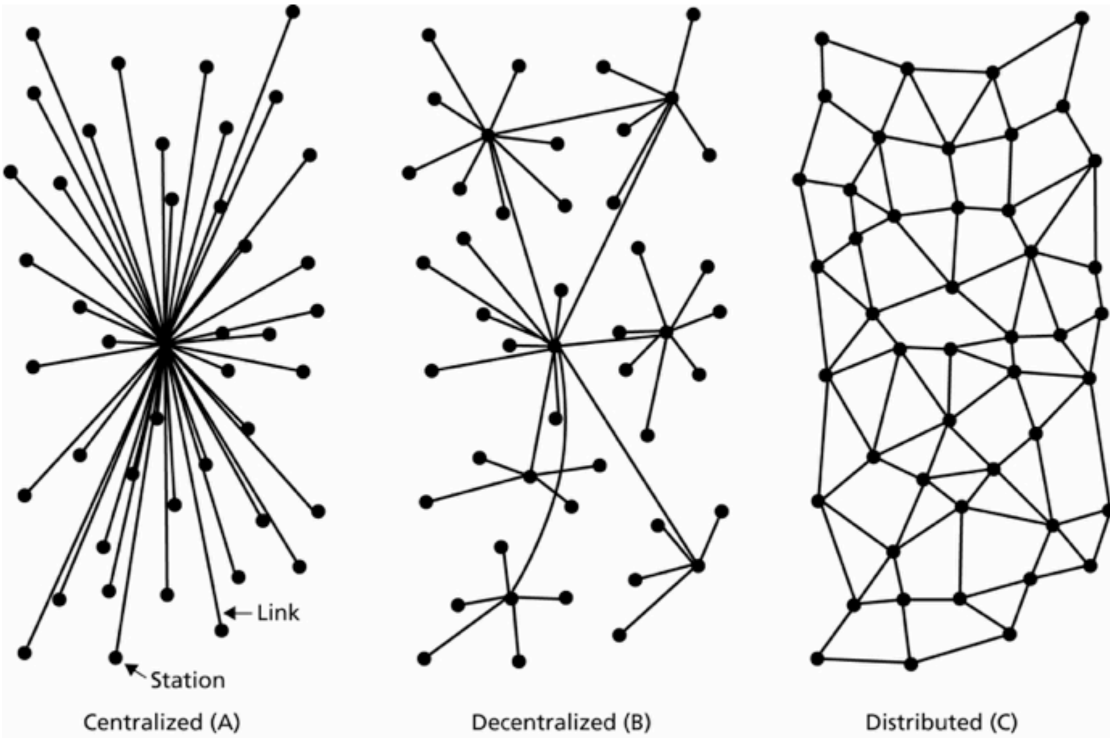



Figure 2: Centralized, decentralised and distributed networks (Source: Baran, 1964)

> "... control and power is taken from a few key positions in the organisations and distributed more widely across the organisation."

# blockchain and the construction industry.

The nature of the construction industry makes it suitable for using blockchain, as the industry is unique in that it brings together multiple project stakeholders with various specialisations and interests to build quality infrastructure within time and budget constraints.

However, the fragmented and adversarial nature of the industry has long been criticised for inefficient processes and low levels of productivity (McNamara & Sepasgozar, 2018; Shojaei, 2019). Low-trust, disputes and win-lose attitudes result from these adversarial relationships (Farshid, Tayyab, & Khalfan, 2017; Fernandes, Costa, & Lahdenpera, 2017). Hence, traditional contracts prevent the industry from achieving the desired project outcomes (Ey, Zuo, & Han, 2014).

The construction industry can be classified as a complex product systems industry, which requires individuals or entities of different skillsets and industries to work together for the duration of their association with the project and discontinue on completion (Erri Pradeep, Yiu & Amor, 2019). By 2022 construction spending is forecasted to reach US$12.4 trillion (McKinsey Global Institute 2017). Currently, the construction industry is encountering many challenges such as lack of adequate collaboration and information sharing, low productivity, poor regulation and compliance and poor payment practices (Li, Greenwood & Kassem, 2019).

> “ ... innovation and investment in technology in the construction sector is the key to unlocking greater productivity. ”

> “ Blockchain smart contracting is an emerging technology that may solve the industry’s challenges by redefining trust, improving transparency, ensuring timely payments and increasing efficiencies in workflows. ”



There are growing interests in collaborative contract arrangements within the industry (Ey, Zuo, & Han, 2014; Farshid, Tayyab, & Khalfan, 2017). Corporations like the New Zealand Transport Agency (NZTA) are adopting alliancing for large, complex infrastructure projects (NZTA, 2020). Collaborative arrangements aim to build beneficial relationships between project stakeholders and align their interests for best-for-project outcomes (Farshid, Tayyab, & Khalfan, 2017; Fernandes, Costa, & Lahdenpera, 2017; Ey, Zuo, & Han, 2014). Thus, collaborative contracts improve productivity, reduce contractual disputes and better deliver large projects within time and budget constraints (Elhag, Eapen, & Ballal, 2019; Farshid, Tayyab, & Khalfan, 2017). However, low-trust, varying levels of commitment and commercial pressures rooted in the industry’s adversarial nature inhibits collaborative agreements (Elhag, Eapen, & Ballal, 2019; Ey, Zuo, & Han, 2014).

Chang-Richards, Brown and Smith (2019), suggest that innovation and investment in technology in the construction sector is the key to unlocking greater productivity. Technologies such as design automation will reduce the design errors and increase the precision of design. To improve information exchange in the construction industry, information technology is being adopted. A study highlighted information exchange that was welcomed by industry users (Erri Pradeep, Yiu & Amor, 2019). On the other hand, Li, Greenwood and Kassem (2019), emphasize that the inability to embrace and adopt technological advancements is hindering the modernisation of the construction industry, as the industry is slow to innovate. This is because a substantial investment is required for technological advancements. However, if the adoption is properly planned and executed the longer-term benefits include a reduction in cost and increase in profit margins will outweigh the investment cost.

Blockchain smart contracts is an emerging technology that may solve the industry’s challenges by redefining trust, improving transparency, ensuring timely payments and increasing efficiencies in workflows (Underwood, 2016; Turk & Klinc, 2017). Essentially, a blockchain smart contract is a digital agreement stored on a blockchain comprising of a set of instructions that are automatically executed when conditions are met (Cardeira, 2015; Cohn, West, & Parker, 2017). While blockchain smart contracts are in more advanced stages of research and implementation in other industries, research for its use in construction is limited (Li, Greenwood, & Kassem, 2019).

# chip of the new block(chain): a research project.

This section describes and reports ongoing research, the central question being 'what opportunities does blockchain present to construction and the associated disciplines of architecture and engineering?' The research project 'Chip of the New Block(chain)' ran from October 2018 to October 2020. The report here is on the first phase of the project, which comprised of industry workshops.

The methodology used here has been developed by the Design Informatics Research Centre at the University of Edinburgh. Research is also underway there to investigate applications of blockchain. The activities deployed through the workshop format are intended specifically to engage people with a non-technical background. Typically in large organisations people in positions of strategic influence have a limited knowledge of specialist and emerging technology. Thus they are likely to miss potential opportunities where an innovation might benefit their organisation. The aim of this project is to engage such people, introduce blockchain and its affordances with non-technical activities and focus on strategic opportunities for their organisations or businesses. Greater detail on the methodology can be found on the Design Informatics website [1].

During 2019 the research team conducted a series of inter-disciplinary workshops with industry participants to deepen their understanding of blockchain and assist in delineating key streams of research into how it might reshape aspects of the sector. The workshops are comprised of three phases (1) an introductory overview (2) a 'trading' card game, and (3) an ideation and brainstorming session.

The first phase provides a general history of and context for blockchain, similar to the content presented in section 2 of this paper. As many of the workshop participants will have little knowledge of the technology the aim of this phase is to provide a simple grounding. There was a second aim to this phase which was to introduce some of the language or 'ontology' common to the subject, which would be used throughout the workshop. There is research which suggested developing and establishing a pre-ontology can be helpful in negotiation and discourse, particularly between different disciplines who often have developed their own meta-ontology [2].

The second phase was a simple trading card game designed by the Design Informatics Research Centre at the University of Edinburgh. In sub-groups of 5-7 participants bought and sold cards, representing commodities, with blocks of Lego, representing currency. Once a trade was complete the Lego block representing currency was initialled by the buyer and seller. These blocks were built onto a central and visible Lego base-plate; this represented the adding of information to a central blockchain. The aim of this phase was to give participant a tangible way to experience two aspects of blockchain technology. We discussed in section 2 of this paper why blockchain is such a difficult concept to grasp. Although the Lego blockchain differs in some ways it assists in conveying the three affordances we discussed in section 3:

- You can see a public world view of transactions.
- It is distributed not hierarchical governance.
- Makes possible a trusted 'audit' trail.

In the third phase of the workshop participants again broke into smaller sub-groups and were encouraged to brainstorm specific aspects of their business that could be reorganised with blockchain. They were then challenged to develop a detailed proposition of what that might look like; what the benefits would be and who would benefit. This phase of the workshop was foregrounded with the use-cases and analysis presented in section 3 of this paper. The use-cases are deliberately taken from different sectors. This intention is to reduce people's proclivity for making very direct translations from the use-case to their industry. For example showing an example of 'blockchain applied to BIM' (building information modelling), and having participants suggest the same idea. This was to focus the participants—a relatively novice group to blockchain—on the novel aspects of blockchain technology. The aim of this phase was to enable industry participants to leverage their knowledge and insights to identify specific opportunities where blockchain could benefit the construction sector.

The workshops take 3-4 hours to complete and 4 were conducted across a wide geographical area during 2019. We report in the next section on some of the outcomes from those workshops.

# Results and discussion

The workshops resulted in a very broad cross-section of potential use-cases. From pragmatic industry-centric 'smart contract' ideas to tangential concepts for crypto-currency that supports community development, and the creation of a 'token economy' for incentivising waste reduction in the construction sector. The themes and situations we explore in this report are directly drawn from those workshops. The report will focus on smart contracts and their potential application within the construction sector.

# Smart contracts

The topic of contracts, indeed procurement in general, has been identified as a significant factor in affecting change for the sector. During the 1990s the canonical Latham and Egan reports focused on this issue in the UK [3,4]. These reports led to the introduction of new ways of procuring buildings, most notably public private partnership or PPP as they were widely known. The aim of the change was to deliver a project with better and more accurate costing and construction scheduling. The results were mixed, and have been discussed by other researchers in some depth [5,6]. More recently collaborative procurements have emerged and have seen positive results [7]. These aim to distribute profit or loss and engender a more collaborative spirit between participants than is found in traditional buyer/supplier contracts in the construction sector [8].

Although collaborative procurement is an improvement on traditional contracts, issues remain. Take a specific form of collaborative procurement—Alliance contracting—typically used on infrastructure projects in New Zealand. While case studies report positive results, this type of novel collaborative project structure typically operates at a high level [9]. It might include clients and several main contractors. Beneath this much of the work of sub-contractors and suppliers continues to be in the form of traditional 'buyer supplier' contract relations. Which usually mean meeting the terms of the agreement by delivering the cheapest possible solution in the quickest possible time. In addition, contracts are typically for one project only. Building a long-term relationship requires an informal agreement based on trust. Furthermore, it is difficult to check all indemnity insurance, professional accreditations and health and safety certifications. While it may occur at the outset of a project interim checks for expiration are more difficult and typically continue on 'trust. So, while on the surface construction may seem to be based on formal contractual processes, our workshops revealed that some key aspects of the industry remain informal and based on trust. This report focuses on these processes and relationships within the construction sector, and the opportunities that smart contracts specifically present to the sector. In the next section we explain existing contract structure and why there are benefits to focusing research 'downstream' on small and medium sized enterprise processes and relationships.

# benefits of blockchain: smart contracts.

## 1. Performance monitoring of suppliers

We are familiar with 'buyers' and 'sellers' performance being monitored, ranked and rated on digital platforms like ebay. However, when a construction project is completed the performance of participants lives mainly in collective memory, and fades. Finding out how well a supplier performs; how accurately a contractor tenders; or how timely a sub-contractor completes their work is accomplished by word of mouth and making enquiries or through experience. Digital commerce platforms like ebay have normalised the expectation that a buyer or supplier has been 'ranked' and feedback is available on their pervious performance. A benefit of implementing smart contracts is the potential to greatly expand this feature.

For example, with the implementation of a smart contract recorded on a blockchain it becomes possible to agree and record salient information such as: start date and completion date (both projected and actual) and did these dates change; what was the tendered amount for the contract, and did the tendered amount of the contact change over the duration. Over time all this data can be used for assessing performance, with good performance likely to result in more contracted work.

" There also may be fewer disputes due to contract breaches and late penalties, consequently resulting in fewer business failures. "

## 2. Improved transparency and trust

Difficulty in establishing trust between competitors was identified as a barrier to successfully implementing collaborative agreements (Ey, Zuo, & Han, 2014). Blockchain smart contracts have the potential to make the contracting processes more transparent. Improved transparency is achieved by distributing identical copies of the transactional information to all the participants on the blockchain network. Consequently, this may reduce disputes between parties by minimising miscommunication and contractions found in traditional paper contracts (Christodoulou, Christodoulou, & Andreou, 2018; Erri Pradeep, Yiu, & Amor, 2019). In comparison to cloud-based systems, the immutable characteristic native to blockchain along with more explicit and reliable information can facilitate a form of digital trust between alliance partners. Furthermore, the transparency and chronological order of the transactions on the blockchain enables the participants to track progress and identify bottlenecks within the contracting process. Thus, the party at fault can easily be identified if a dispute arises.

## 3. Semi-automation of the existing process

The construction industry is notorious for its hesitancy in adopting new technologies. However, relative to other emerging technologies, smart contracts are easier to use. The advantage of blockchain smart contracts is that the blockchain can take parts of the existing process and semi-automate them. Thus, construction professionals and site crews will not need to learn an entirely new process or require extensive training. Furthermore, as the process is semi-automated, the smart contract can cope with the dynamic nature of the industry better. (Mason, Intelligent Contracts and the Construction Industry, 2017).

## 4. Immutability and legal ramifications

The immutability of the blockchain smart contract means that it becomes near impossible to remove or tamper transactions (Zheng, Xie, Dai, Chen, & Wang, 2017). For contracting processes, this may relieve tensions associated with establishing trust. The immutability of the blockchain smart contract also provides an advantage over other technologies and software. The technology can be used as a legal digital document that may assist in dispute resolution by holding the party at fault accountable. Since the transactions on the blockchain are transparent and validated regularly by opposing parties, disputes can be resolved more quickly. Furthermore, the legal ramifications of digitally signing the smart contract are more explicit, and they are presented to the validator via a summary screen. Consequently, when a dispute arises between parties, neither party is in a better or worse off position. This level of transparency and trust is much harder to achieve in cloud-based database systems.



## 5. Faster payments for suppliers

Poor payment practices are identified as one of the construction industry's most significant challenges (Cardeira, 2015; Zheng, Xie, Dai, Chen, & Wang, 2017). Furthermore, many smaller firms, suppliers and subcontractors spend significant amounts of time validating or following up payments (Mason & Hollie, 2018). However, for both of the contracting processes, timely payments can be ensured by embedding escrow into the smart contract. As a result, when specific obligations are met, and the validator digitally signs the smart contract, the payment is released immediately. Timely payments would help to reduce disputes arising from late payments and reduce the time spent following up payments. Consequently, construction firms can spend more time on higher-value tasks and avoid the cash flow issues that cause insolvencies (Wang, Wu, Wang, & Shou, 2017).

> "The construction industry is notorious for its hesitancy in adopting new technologies. However, relative to other emerging technologies, smart contracts are easier to use."

# traditional contracts: alliancing.

In the New Zealand economy, the construction sector has been a constant underperformer. Due to the very challenging operating characteristics, low productivity has been highlighted. Low productivity emphasizes poor risk management practices.

This was highlighted in a survey report when two tiers of businesses were recognised across the industry. The first tier was made of companies with strong financial statements, while the second-tier businesses were prone to industry challenges. If a second-tier business does not manage their risk appropriately, they might be forced to exit the industry. This has been seen over the past year after the failure and collapse of some construction firms. The primary lever for influencing risk levels and practices within the sector is procurement (Chang-Richards, Brown & Smith, 2019). There are numerous procurement options available for construction projects with each option accommodating different project needs (Wilkinson & Scofield, 2010), and choosing the right procurement method is largely driven by the most appropriate way to manage risk (Office of the Auditor-General, 2013).

In New Zealand, the most common procurement system is traditional procurement. In a traditional procurement system, a project team is appointed by the client consisting of design professionals and other consultants depending on the requirements of the project. Following the tendering process, the site is handed over to the contractor with the successful tender. During the building stage, the role of the design professionals may include the administration of the contract. They may need to manage the project on behalf of the client. The design professional must communicate with the client and other various project participants to ensure that the construction is consistent with the design. The client will have a contract with the design professionals, the contractor, and other required consultants (Wilkinson & Scofield, 2010).

In New Zealand, new forms of delivery methods, such as Collaborative procurement are being tested. These include Alliancing (Figure 3), Joint Ventures and Private-public partnerships. For an Alliance project, the companies participating form a single entity, while operating independently outside the alliance project. Depending on the level of contribution to the Alliance project, the risks and rewards are shared between the parties according to a pre-agreed arrangement. The different entities partner up to achieve the specific business objective, the teams work together in good faith with "no disputes" arrangement and fostering a "no blame" culture (Office of the Auditor-General, 2013).

Recently in New Zealand, an alliance form of contract was used to procure City Rail Link's work package C3 Alliance (City Rail Link Ltd, 2020).
An alliance contract was used because the risk of the project is highly uncertain, and the project, which includes mining tunnels, is highly challenging. The winning alliance is called Link Alliance. Link Alliance comprises of Vinci Construction Grands Projets S.A.S, Downer NZ Ltd, Soletanche Bachy International NZ Limited, WSP Opus (NZ) Limited, AECOM New Zealand Limited, and Tonkin + Taylor Limited. An alliance will have a high level of knowledge transfer between each other (Ministry of Business, Innovation and Employment, 2020). Furthermore, an Alliance approach was used in the United Kingdom to construct Terminal 5 of the Heathrow Airport. This is because the project presented several challenges such as high material risk, large scale and design expected to change during the project (Office of the Auditor-General, 2013).

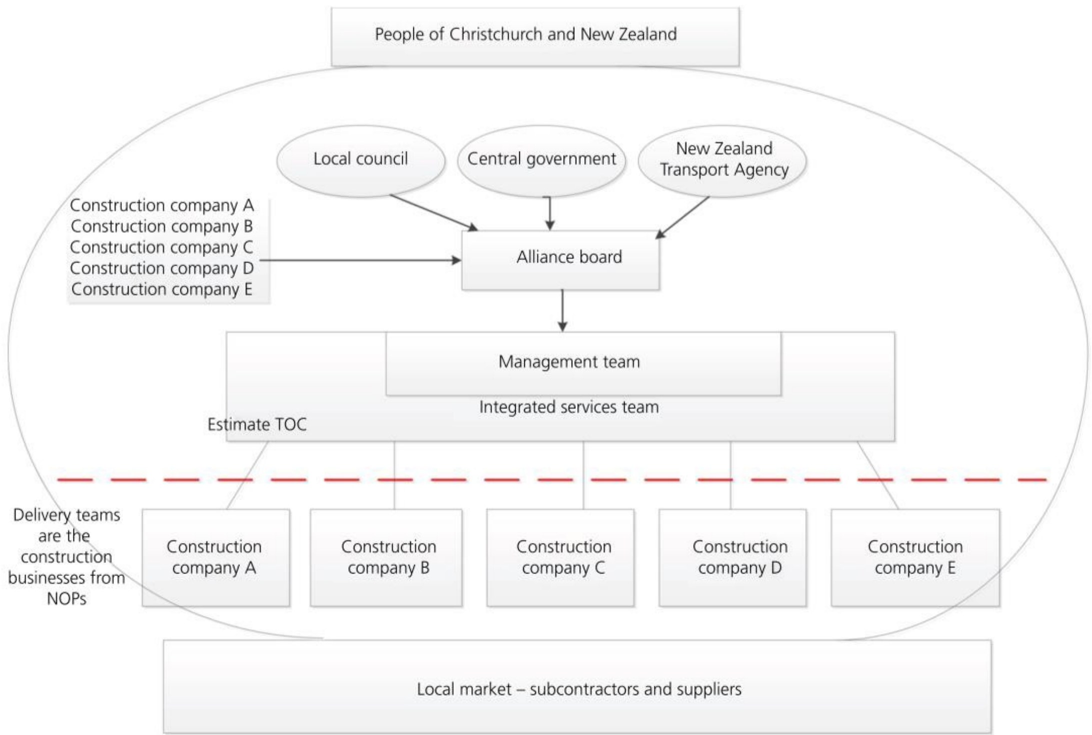



Figure 3: Showing SCIRT's alliance structure. Adapted from "Christchurch rebuild, New Zealand: alliancing with a difference" By Botha & Scheepbouwer, p.123.

> “ The constant inefficiency of the construction sector is due to the low productivity, poor risk management practices and poor payment practices. ”

The benefits of the alliance approach include increased agility to deal with an evolving scope, a high degree of trust between parties and focus on high-performing expectation, increased general workforce skill levels reduced overheads, streamlined approval, and pricing risk accurately and understanding the risks in the contract (Chang-Richards, Brown & Smith, 2019).

The constant inefficiency of the construction sector is due to the low productivity, poor risk management practices and poor payment practices (Erri Pradeep, Yiu & Amor, 2019). Different procurement methods are the key in allocating risk more effectively in construction projects (Chang-Richards, Brown & Smith, 2019). In an Alliance procurement method, the risks and rewards are shared between the parties according to a pre-agreed arrangement. Other benefits of an Alliance procurement method include increased agility to deal with an evolving scope and focus on high-performing expectation (Wilkinson, S & Scofield, R, 2010). Also, it is suggested that innovation and investment in technology in the construction sector could unlock greater productivity (Chang-Richards, Brown and Smith, 2019). Technology such as blockchain smart contracts can revolutionize the construction industry (Ahluwalia, Mahto, & Guerrero, 2020). The features of smart contracts such as if/then commands, reduce the need for intermediaries, and minimise the amount of physical paperwork (Li, Greenwood & Kassem, 2019). This combined with the in-built features of blockchain such as decentralisation, immutability, etc have the potential to transform the Construction sector and solve many of the problems that it is currently facing. As it may also redefine trust in an Alliance contract, which is highly crucial and beneficial for all Alliance participants (Ahluwalia, Mahto, & Guerrero, 2020; Hughes et al., 2019).

# generalised alliance contract structure.

This section presents the findings of this research based on the SCIRT Alliance case study, which was verified using other case studies and literature. Figure 4 shows a generalised alliance structure based on the SCIRT Alliance and the NEC4 Alliance Contract.

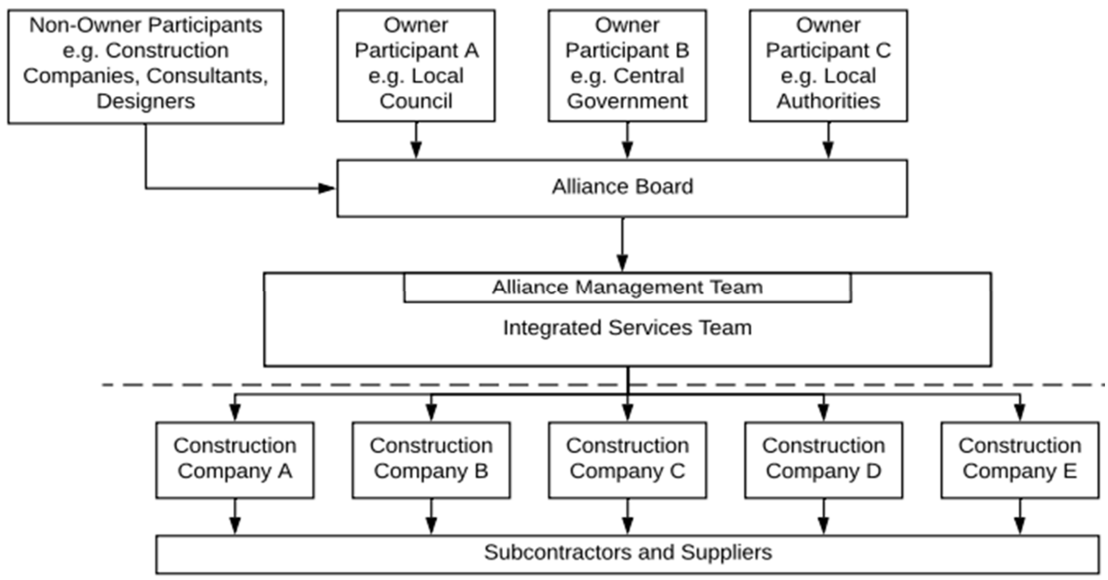



Figure 4 : Generalised alliance structure. Adapted from "Effectiveness and efficiency of arrangements to repair pipes and roads in Christchurch" by Office of the Auditor-General, 2013, p.18.

As shown in Figure 4, the alliance board comprises the owner and non-owner alliance participants. The owner participants may include local councils, the government, government agencies and local authorities. The non-owner participants may include contractors, consultants, and designers. The owner and non-owner participants have one alliance board representative each and share the majority of the risks under the contract (Office of the Auditor-General, 2013).

According to the NEC4 (New Engineering Contract) Alliance Contract, the owner participants establish the alliance objectives and the scope of works. Furthermore, the owner participants select the non-owner alliance participants, undertake cost and quality assurance procedures and make payments to the alliance participants (Introducing the new NEC4 Alliance Contract, 2018). The alliance board has overarching responsibility for the alliance. The alliance board administers the alliance agreement, assigns the alliance manager, makes unanimous decisions on a best-for-project basis and mediates disputes between alliance partners (Introducing the new NEC4 Alliance Contract, 2018; Office of the Auditor-General, 2013).

The integrated services team comprises professional and support staff from each of the alliance participants. Thus, the team is responsible for the delivery of the project, including design and construction (Office of the Auditor-General, 2013). The alliance management team is part of the integrated services team and is responsible for the day-to-day management of the alliance (Office of the Auditor-General, 2013). The alliance management team is led by the alliance manager, who manages the contract and follows directions from the alliance board (Introducing the new NEC4 Alliance Contract, 2018). The construction companies who are members of the alliance and their subcontractors and suppliers deliver the contract work. The construction companies within the alliance compete for work based on their performance and capabilities (Office of the Auditor-General, 2013).

The generalised alliance structure in Figure 4 indicates that there are two possible areas where smart contracts can be applied in an alliance contract. The first is the upper part of the alliance structure above the dashed line in Figure 4. The second is the bottom part of the structure below the dashed line. Findings show that the alliance governance in the upper part of the structure varies between project alliances to suit the project better (Che Ibrahim, Costello, Wilkinson, & Walker, 2016). Thus, a smart contract for the processes in the upper part of the structure is relatively more difficult to prototype using a case study approach. Furthermore, the upper part of the alliance structure encourages collaboration between alliance participants through the unanimous decision-making processes and greater transparency. Conversely, the delivery of the alliance work involves subcontractors and suppliers who may not be members of the alliance and instead hold traditional forms of contract. Consequently, smart contracts applied in the bottom part of the alliance structure would likely provide more significant benefits by removing adversarial contract relationships and improving transparency. Upon further investigation of the contracting processes in the bottom part of the structure, the material procurement process and the payment process were considered to offer promising applications of blockchain smart contracts.

# smart contracts for construction.

## MATERIAL PROCUREMENT

Material procurement has been identified as a process which is repetitive within Alliance Contracts, as well as the construction industry. 40-45% of the overall cost of all construction is for the construction materials. Every company needs to be efficient and have an effective material procurement strategy to reduce administration costs and remain competitive in the Construction environment (Kong et al., 2004).

Thus, material procurement was considered a viable contracting process to analyse further. Figure 5 shows the typical material procurement process for a construction project. The process involves site management, the site foreman or supervisor, cost accounts, and the supplier. Typically, the process is initiated when the site manager requests a quote from the supplier. Upon acceptance of the quote, the site manager sends a purchase order for the material to the supplier. Once the supplier approves the purchase order, the material is delivered to the construction site on the agreed delivery date. At the construction site, the site foreman or the site supervisor checks that the content on the delivery truck matches the packing slip. Then the packing slip is retrieved by the site manager who checks it against the purchase order, before storing it in a folder or a database on the computer. When cost accounts needs verification of costs or invoices sent by the supplier, the site manager needs to look through a trail of paperwork to verify the cost. Cost accounts makes a payment to the supplier once the invoice is verified.

“ When cost accounts needs verification of costs or invoices sent by the supplier, the site manager needs to look through a trail of paperwork to verify the cost. ”

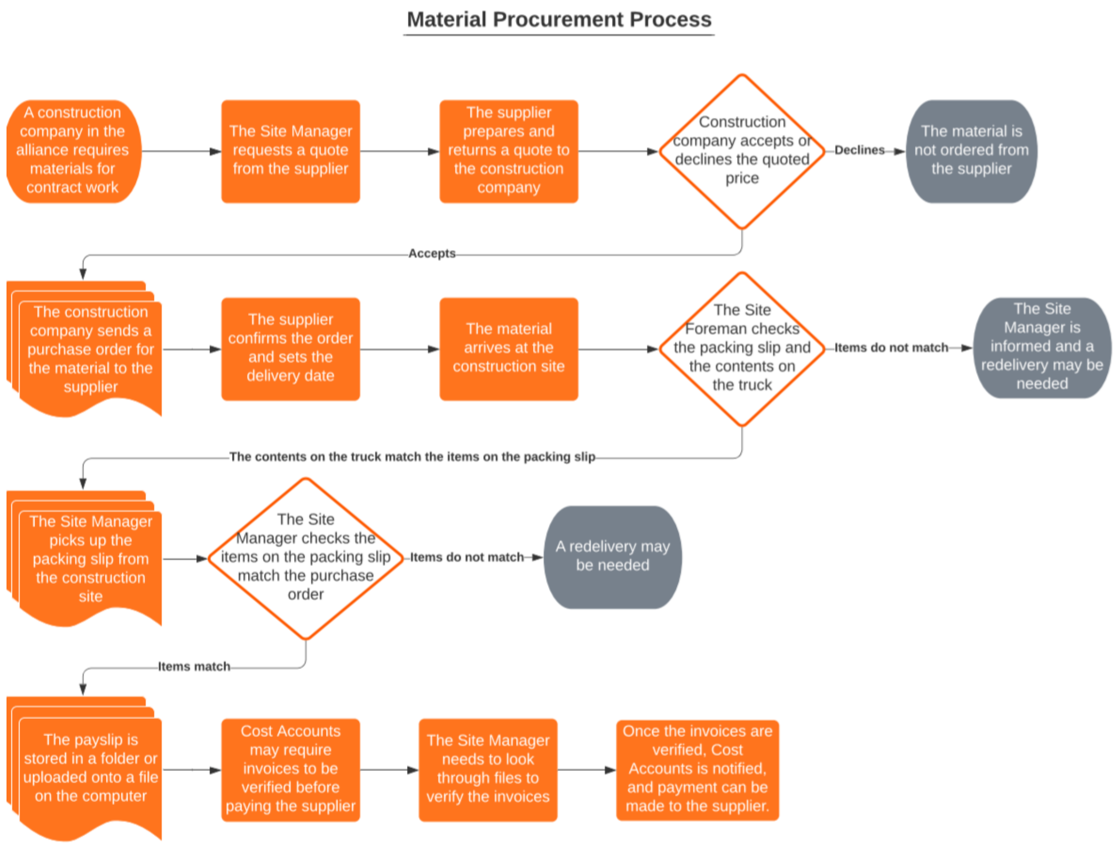



Figure 5 : Typical material procurement process. Source: S Singh.

There are several challenges in the material procurement contracting process. The sheer volume of paperwork and fast-tracked work in an alliance project makes coordinated and transparent documentation difficult. A discrepancy between the purchase order and the packing slip may not be realised until the site manager verifies the packing slip in the site office. This is because the site foreman or supervisor does not have access to the purchase order and can only confirm the contents on the truck match the packing slip. Moreover, on large alliance projects, it may take several days before packing slips or other relevant documentation reach the site office. During this time, the document can be damaged or lost. Furthermore, when invoices, claims or costs need verification by cost accounts, the site manager undertakes the time-consuming task of looking for the filed documentation. Consequently, the site manager has less time for higher-value tasks such as managing health and safety and addressing project stakeholder requirements. Additionally, delays in this verification process may result in cost accounts paying for items that the construction crews did not receive or delay payment to the supplier.

> “The sheer volume of paperwork and fast-tracked work in an alliance project makes coordinated and transparent documentation difficult.”

# SMART CONTRACT IMPLEMENTATION FOR THE MATERIAL PROCUREMENT PROCESS

Given the reoccurring nature of the material procurement process, smart contracts may be a viable solution to the aforementioned challenges. The application of a smart contract for the material procurement process is shown in Figure 6 and closely follows the process outlined in Figure 5. However, the smart contract begins when the site manager accepts a quote and uploads the approved purchase order onto the blockchain with his/her digital signature.

The quotation process is not included in the smart contract because unaccepted quotations do not add significant value and may confuse participants on the blockchain. Moreover, storage space is limited on a blockchain. Thus, only the essential steps should be on the blockchain and not the entire process.

The smart contract will then prompt the supplier to check and digitally sign the smart contract to confirm delivery. Before the material is dispatched, the supplier will need to upload and check their packing slip, and digitally sign the smart contract. When the materials arrive on site, the site foreman digitally signs the smart contract to confirm the materials on the truck match the packing slip. Unlike the traditional process, the site foreman has access to the purchase order approved by the site manager. Once cost accounts have verified the relevant invoices and costs, they will sign the contract and make a payment to the supplier.

The purchase order, packing slip, invoices and costs are verified regularly, and discrepancies can be identified at each step. Additionally, blockchain smart contracts may reduce the paper trail since all the documents are stored on a single blockchain that is shared with the participants on the network. Consequently, less time is spent recovering lost or damaged documentation. Furthermore, the smart contract eliminates the need for the site manager to verify construction costs and invoices. There is an opportunity for a direct relationship between the site staff and cost accounts. Consequently, the application of a smart contract can streamline the process, allowing site managers to spend more time on higher-value tasks. Moreover, a streamlined verification process may encourage timely and complete payments to suppliers, provided funds are available.

“ Given the reoccurring nature of the material procurement process, smart contracts may be a viable solution ... ”

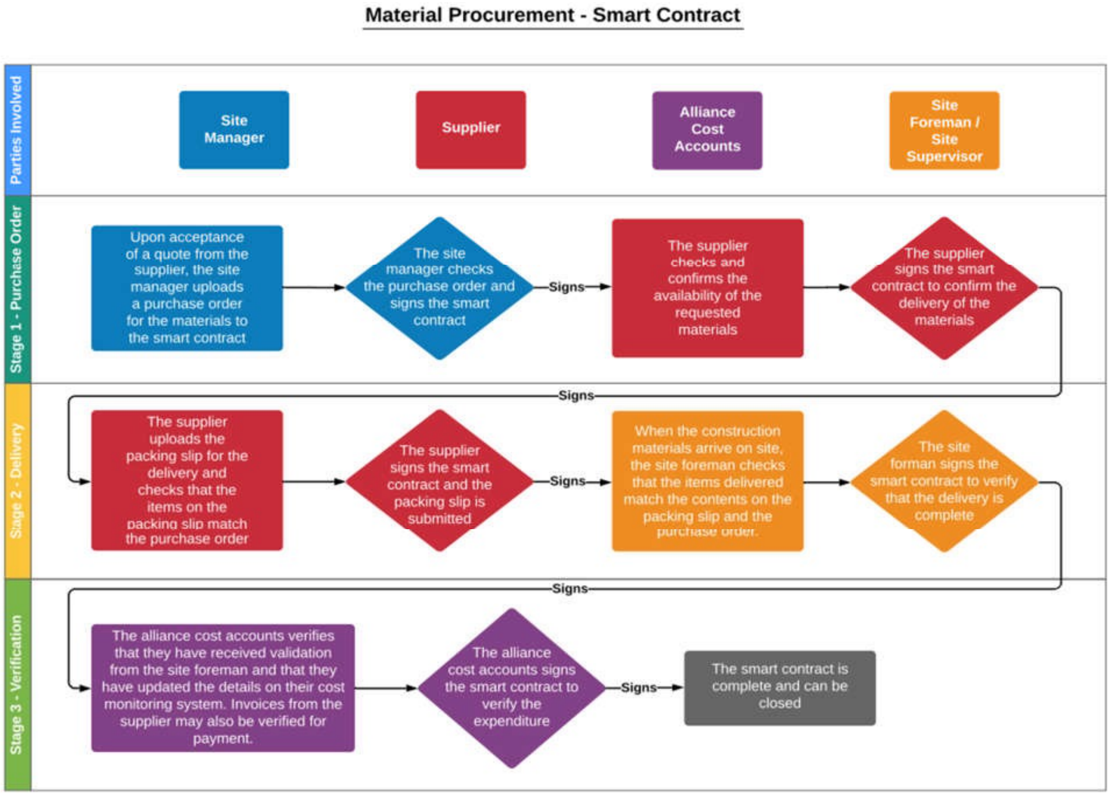
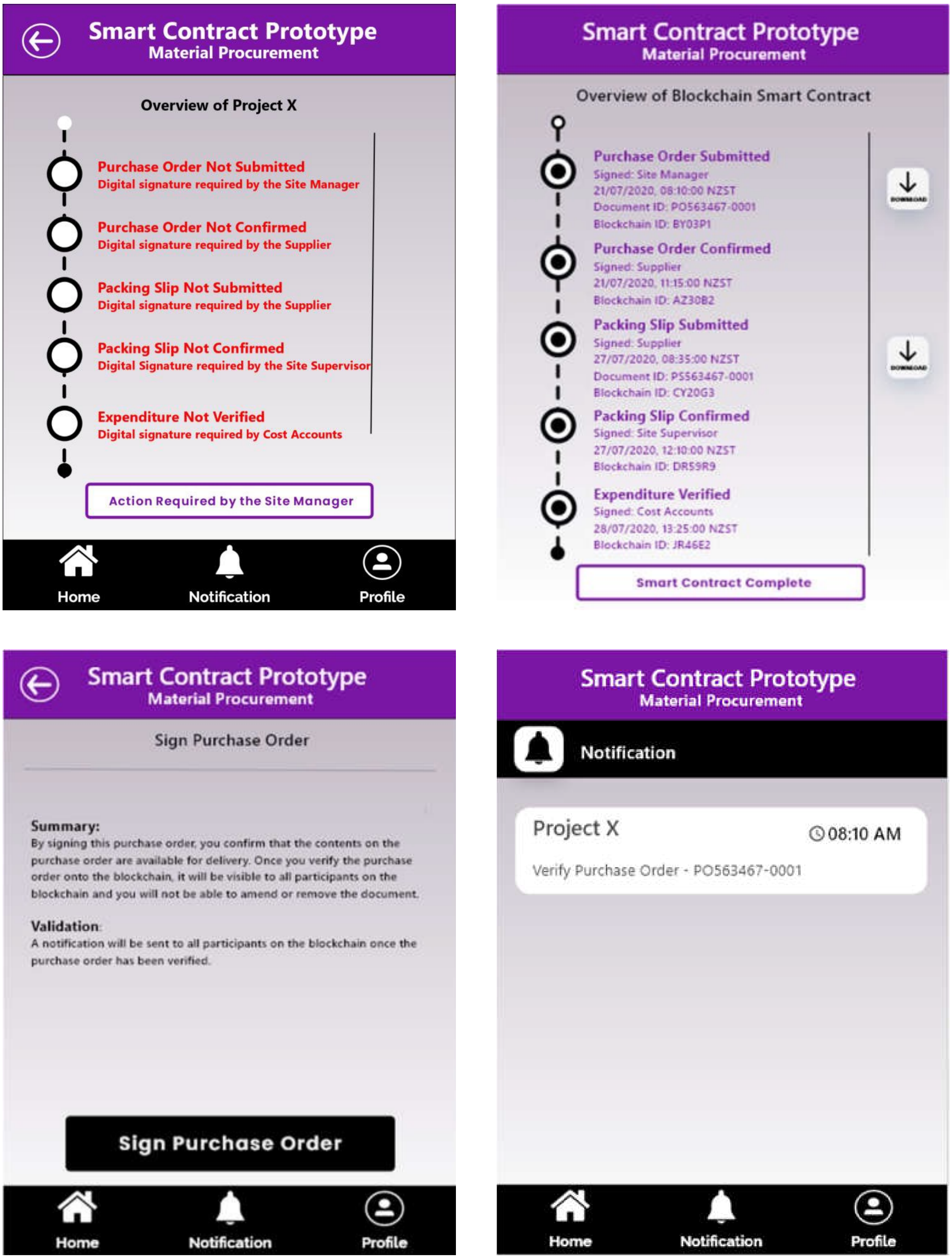



Figure 6 : Smart contract flowchart for the material procurement process. Source: S Singh.

The Oxchain smart donations app (Oxchain, 2020) and the IBM and Maersk cross-border supply chain solution (IBM, 2020) methodologies were applied to prototype the smart contract for the material procurement process outlined in Figure 6 on Adobe XD. The methodologies enabled the process to be modelled where a distinct action is required by a participant on the blockchain network. Figures 7 and 8 show the overview screen of a smart contract. The overview screen allows the participants on the blockchain network to view the progress of the material procurement process at any given time. Furthermore, they will be able to access the documents submitted onto the blockchain along with information on who signed off each step and at what time and date.

Figure 9 shows the sign-off summary screen presented to the supplier once he/she has reviewed the purchase order submitted by the site manager. The sign-off page provides a clear summary of the ramifications of digitally signing off the purchase order to the supplier. The supplier is also informed that all the other participants on the blockchain will be notified once he/she has validated the purchase order. Furthermore, the sign-off page prevents the supplier from accidentally signing the smart contract and protects the user from the immutable characteristic of the blockchain technology. Figure 10 shows the notification screen where a participant on the blockchain may be prompted to take a specific action. The purpose of the notification screen is to ensure that an action is brought to the participant's attention and that he/she can easily access it.




CLOCKWISE FROM TOP: Figure 7: Material procurement overview screen; Figure 8: Material procurement overview screen, further through the process; Figure 9: Purchase order sign -off summary screen; Figure 10 : Material procurement notification screen. Source: S Singh.

The prototype is demonstrated at https://youtu.be/W7NzEU7TWMg

# THE PAYMENT PROCESS

In the construction industry losses and delays to payments are a key concern. For over four decades, the problems regarding payments has been recognized and examined. The problems include the Contractors getting paid late, or not getting paid for the work performed (Ramachandra & BamideleRotimi, 2015). This increases the risk of the Contractors becoming insolvent (Ramachandra & Rotimi, 2015).

The payment process for the SCIRT alliance is shown in Figure 11 and was developed from a case study on the SCIRT alliance. The payment process includes the design consultants, the contractors within the alliance, the alliance manager and less often the alliance board. Based on the SCIRT alliance case study, the design consultants were not members of the SCIRT alliance. However, the contractors were members of the alliance (Botha & Scheepbouwer, 2015; Office of the Auditor-General, 2013). The design consultants procure the design work packages from the alliance based on the procurement management plan. The procurement process considers a design consultant's knowledge and experience; the typical cost and time for the consultant to design a standard quantity of work; the quality of the consultant's design reports; and the resources the design consultant has available. The alliance will offer a cost-reimbursable contract to the successful design consultant such that most of the financial risk is carried by the owner participants of the alliance (Botha & Scheepbouwer, 2015).

Following the procurement of the design work, the design consultants produce a complete set of construction design documentation for the work package. During this process, early contractor involvement (ECI) may be required for complicated or high-risk projects. Upon completion of the construction design documentation, the design consultant submits a payment claim to the alliance manager. The alliance manager verifies if the payment claim is from an alliance partner. As the design consultant is not an alliance partner, the alliance manager may dispute the claim from the design consultant if he/she believes it is unjustifiable. The alliance board resolves all disputes, and once resolved, the alliance manager will pay the agreed amount from the disputation process (Green, 2019). Additionally, if the payment is late, the alliance will accrue interest cost on their payment. If the payment claim is not disputed and the alliance cannot make the payment on time, the design consultant may suspend works until they receive payment.

"In the construction industry losses and delays to payments are a key concern. For over four decades, the problems regarding payments has been recognized and examined."

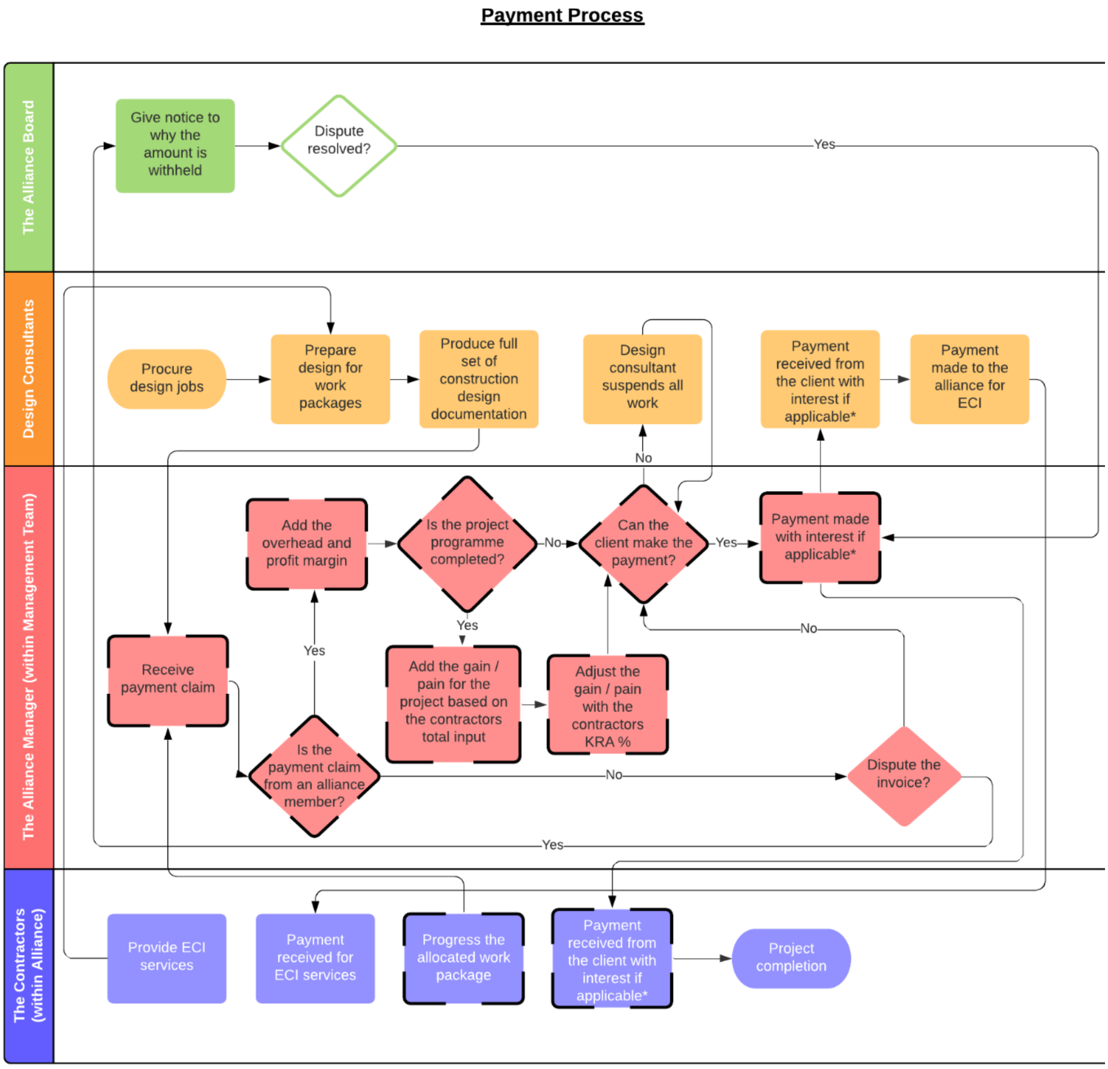



Figure 11: Payment process based on the SCIRT alliance. Source: A Kumar.

Once a contractor has been assigned a work package, they will undertake the work defined in the work package. As per the Alliance Agreement, the contractor will need to attach their construction schedule and an earned value analysis to their payment claim (Botha & Scheepbouwer, 2015). These documents should be submitted to the alliance manager by the specified date of the month, as stated in the Alliance Agreement (Botha & Scheepbouwer, 2015). The construction schedule outlines the progress made for each activity within the work package. The earned value analysis provides evidence of the contractor's progress to date and whether delays or cost overruns are likely. It is important to note that the alliance manager may not dispute claims from the contractor unless he/she suspects that there has been a breach of the contract agreement (Green, 2019).

Once the alliance manager assesses and accepts the payment claim, he/she will add the contractor's overhead and profit margin (Botha & Scheepbouwer, 2015). If the work package is still in progress, the alliance manager makes the payment to the contractor. However, if the work package is complete, the alliance manager will adjust the payment according to the total gain or loss on the project (Botha & Scheepbouwer, 2015). The total gain or loss is typically shared between the non-owner alliance partners and the owner partners equally (Botha & Scheepbouwer, 2015). The non-owner alliance members will share their portion of the gain or loss based on the proportion of the total work they undertook for a specific work package. Furthermore, the gain or loss for each contractor is adjusted by ± 10% based on their key results area (KRA) score. The key results area considers a range of key performance indicators which may include safety, the value of work to the client, team and client satisfaction and the environment. The KRA provides contractors with an incentive to consider factors other than cost and time. Once the alliance manager sums the contractor's construction costs, overheads and profit, and share of gain or loss, the payment is made to the contractor (Botha & Scheepbouwer, 2015). It is important to note that the minimum payment to the contractor is for their construction costs. Significant losses that may reduce this minimum payment must be borne by the owner alliance participants (Botha & Scheepbouwer, 2015).

The main challenges with the existing payment process to the alliance partners are that there are inconsistencies with the presentation of the payment claims and that payments can be withheld from the contractors. An audit conducted on the SCIRT alliance found that many of the payment claims were presented inconsistently or were difficult to interpret. Furthermore, fewer claims were validated than expected since the delivery teams did not provide all the required information (Office of the Auditor-General, 2013). Thus, the alliance manager would spend a significant amount of time verifying payments. Additionally, as the contractor is an alliance partner, they are unable to dispute payments unless there has been a breach of the contract. This may result in some contractors being paid late if the alliance does not have adequate finance. Timely payments help to avoid contractors running into cash flow issues.

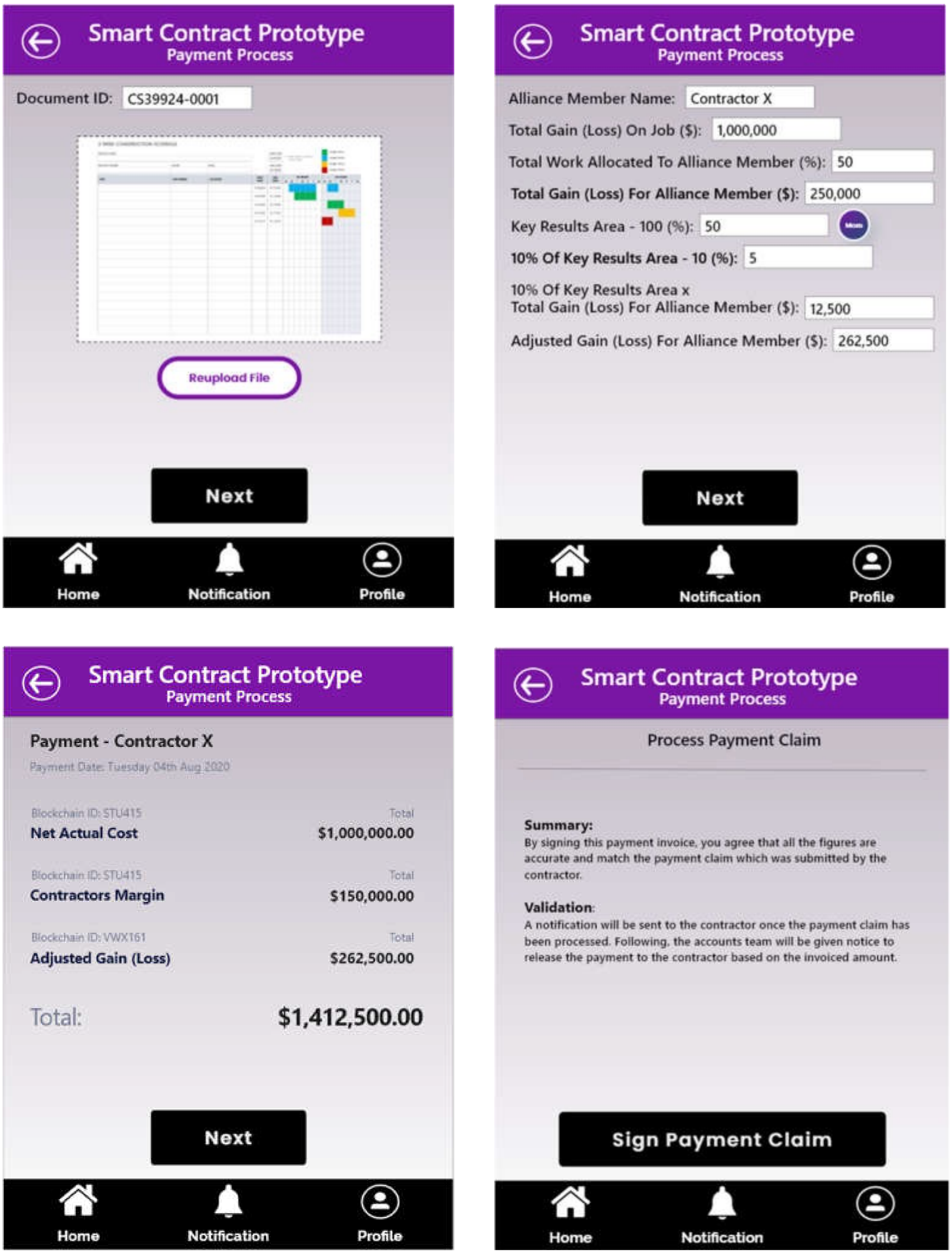
Blockchain smart contracts could be applied to the payment process to overcome the challenges aforementioned. The technology could present the payment process with greater consistency. Furthermore, timely payments to the contractor can be enforced through the use of escrow or an alliance project bank account where the cost accounts team can make prompt payments to the contractor. Thus, the use of blockchain smart contracts can help to ensure that contractors receive payment on time and prevent them from running into cashflow problems. The blockchain smart contract will be applied to the payment process between the alliance manager and the contractor. This process is highlighted in Figure 11. The dispute process has been omitted as it will create variances in the smart contract. As noted earlier, a limitation of the application of blockchain smart contracts would be that the technology does not perform well when there is variability in the process. Furthermore, it is unlikely that blockchain would resolve conflicts between alliance partners without human intervention.

# SMART CONTRACT PROTOTYPE FOR THE PAYMENT PROCESS

Similar to the material procurement process, the payment process between the alliance manager and the contractor was prototyped on Adobe XD. The Oxchain (Oxchain, 2020) and the IBM and Maersk cross-border supply chain solution (IBM, 2020) methodologies were applied to prototype the highlighted parts of the payment process shown in Figure 11. Consequently, the process was modelled through several screens where either the contractor or alliance manager is required to undertake a specified action Figure 12 shows the screen that the contractor will see once they have uploaded their construction schedule.

The screen shows the document ID that can be used to find the document on the blockchain. Moreover, the screen will allow the contractor to review the uploaded construction schedule before digitally signing the blockchain on the next screen. Figure 13 shows the screen that the alliance manager will see when determining the contractor's gain or loss amount upon the completion of a work package. The screen presents the total gain or loss the alliance has made on that work package. As mentioned earlier, the owner and non-owner alliance participants will typically share the gain or loss equally. Additionally, in this case, the contractor has been allocated 50% of the total work for the work package. Thus, the total gain or loss for the contractor is a gain of $250,000. The key results area is 50% out of 100%. According to the SCIRT alliance case study, 10% of the contractor's KRA is taken to incentivise the contractor to consider factors other than cost and time. This means an additional 5% of the total gain or loss for the contractor is added. Thus, the adjusted gain or loss for the contractor equates to $262,500.

Figure 14 shows the contractor's payment summary screen. The screen presents the contractor's net actual cost, which includes the direct costs of undertaking the work in the work package, e.g. construction material costs and labour. The contractor's margin is calculated based on a percentage of the net actual cost; in this case, 15%. The contractor's margin includes the contractor's overheads and profit. The adjusted gain or loss for the contractor accounts for the contractor's share of the total gain or loss to the alliance for a specific work package. The figure for the adjusted gain is taken from the previous screen shown in Figure 13. Furthermore, the total sum of the payment to the contractor is displayed. Once the alliance manager has processed the payment claim, he/she will see the payment sign-off screen shown in Figure 15. The payment sign-off screen summarises the ramifications of digitally signing the payment claim, such as the alliance manager taking responsibility for the payment. Furthermore, the alliance manager is informed that the contractor will be notified once he/she digitally signs the contract. Once the alliance manager digitally signs the contract, the accounts team will be notified to release the payment from the alliance project bank account promptly.




CLOCKWISE: Figure 12 : Construction schedule input screen; Figure 13: Contractor's gain or loss summary screen; Figure 14: Contractor's payment summary screen; Figure 15: Contractor's payment sign-off screen. Source: A Kumar.

# benefits of blockchain: token economies.

Bitcoin is probably the most well-known of the new currencies powered by blockchain. However there are many others. This ability to create unique coins or 'tokens' has inspired a whole new form of 'token economy.' Where new types of tokens are created and traded. In this case we look at how a new token might be used to develop a new type of economy and incentivise waste reduction in construction.

Landfill is a significant contributor to greenhouse gas emissions. It is estimated in NZ that waste from construction makes up approximately 30% of landfill. Reducing waste from construction will have a significant impact on emissions.

The current model of charging to dump in landfill—even with expansion of the national waste disposal levy or subsidizing reuse—has proven to have significant limitations and is inadequate for the required step change. This novel research proposes developing a sophisticated 'token economy' to incentivize a circular economy to reduce waste through leveraging new blockchain technology.

However, the construction sector requires a step change to reduce waste. The current model either charges for waste disposal, a cost which is passed onto the client, or waste minimisation activities are subsidised. By themselves these initiatives are not enough to ensure national and international targets for reducing waste, and the emissions associated with it. While there is a growing reduce, reuse and recycle (the triple R) market, it is artisanal, niche and does not typically involve drawing waste from the construction sector. Although with an emerging trend in off-site prefabrication and assembly there is an increase in high-quality reusable waste and an increase in SME's wanting a reuse solution.

Achieving this requires the following challenges to be addressed:

- In the existing business model waste material has no value, and there is no incentive to try and extract value from it. The easiest solution is landfill.

- Companies that do reuse are typically SME's with limited ability to benefit from collaboration. Although there is an increasing interest by consumers to trade in the triple R market, scaling business in that market is difficult due to access to reusable materials or the ability to trade at a larger scale with larger companies.

- Waste material quickly becomes unusable as supply chain material management only applies until the material is used. Much less care is applied afterwards.

The core focus is on developing novel applications of the emerging blockchain, token economy and similar technologies to foster change towards waste reduction and upcycling. The World Economic Forum has identified blockchain technology as having the potential to better support circular economies and finance projects for environmental change. The technology developed in this programme will support entirely new forms of e-commerce and services within the construction sector. Such as being able to 'program' tokens to only be traded on waste reducing products or services; or the ability for small and medium companies to access finance quickly with reduced red tape, as well as quickly and easily pool tokens to give a group more 'buying power' and incentivise waste being traded back to the reduce, reuse, recycle market and away from landfill.

In the long term this is the creation of an entirely new economic activity for New Zealand. It aims at disrupting the construction sector, where 'top down' change has proved ineffective for the step change required.

> "This novel research proposes developing a sophisticated 'token economy' to incentivize a circular economy to reduce waste through leveraging new blockchain technology."

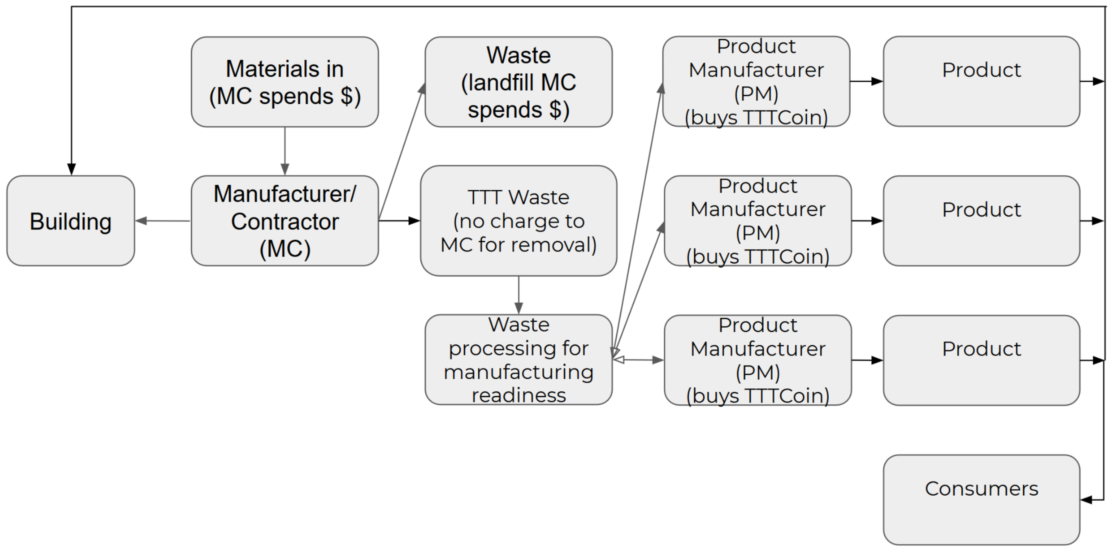



Figure 16: Diagram of the proposed token 'TTTCoin' economy.

# limitations of blockchain smart contracts in the construction industry.

## 1. Limited storage space and scalability of the blockchain

There is limited storage space and scalability of the blockchain technology, as the blockchain technology can theoretically only handle a maximum of seven transactions per second (Erri Pradeep, Yiu & Amor 2019). As a result only selected data from the prototyping process should be stored on the blockchain. For example, the KRA for each Alliance member from the payment process prototype, and the Time and Accuracy of the delivery of materials from the Materials procurement prototype should be stored on the blockchain as these data can be used by the Clients and Site Managers to make more informed decisions and optimise the cost and efficiency of the project as it progresses. However, due to the duration and complexity of Alliance projects it may be difficult to store all the transaction data on the blockchain. For example, the project duration for the SCIRT alliance was over four years (Botha & Scheepbouwer, 2015).

## 2. Cost of implementation

There is a high initial capital cost of implementing blockchain. This, combined with the energy usage after each transaction is processed, may make blockchain an unfavourable solution in Alliance contracts, as $15 million of energy is required per day to run public blockchains such as Bitcoin or Ethereum. As a result, not all construction companies may have the capital funding to implement blockchain smart contracts (Swan, 2015).

# 3. Privacy and security issues

The information stored in the Alliance's private blockchain may be at risk if cyber criminals try to hack and steal the project's sensitive information. As a result, Alliance groups may be deterred from implementing blockchain technology. This is because, if the cyber criminals gain over 50% computational power in the private blockchain, they will have the opportunity to modify previous transactions and steal sensitive information from the project (Erri Pradeep, Yiu & Amor, 2019).

# 4. Immutable data

Another limitation would be the need to ensure that the blockchain smart contract functions strictly as intended, given that details will remain on the digital ledger indefinitely (Frantz & Nowostawski, 2016). The immutable characteristic of the technology may also create issues when an error in the code or input is identified. This is because it is reasonably challenging to fix an error on a blockchain. Additionally, many traditional contract clauses are ambiguous to facilitate legal interpretation. However, the 'yes or no' code used in blockchain smart contracts may be inappropriate for some processes where variations or uncertainties exist. Thus, although the smart contract provides improved transparency, it does not perform well where human interpretation is required.

# 5. Slow technology adoption by the construction sector

The construction industry is hesitant to embrace and adopt technological advancements (Li, Greenwood and Kassem, 2019). As a result, it may be difficult to implement blockchain smart contract into projects. This was further reinforced by Erri Pradeep, Yiu & Amor (2019), as they state that the industry users may be deterred from blockchain technology due to its complexity. The implementation of smart contracts using blockchain technology can be introduced to sectors like construction industry in small stages, where the users are first thoroughly educated about this technology. This may give confidence to the users and prevent them to be overwhelmed by this innovation (Ilbiz & Durst, 2019).

# conclusion.

In this report we have mined deeper into supply chain and specifically looked at comparisons with other case-studies. We have explored some of the affordances of blockchain and the specific opportunities that a 'smart-contract' environment might present to the construction industry. In New Zealand—which has a relatively modest economy—there are limited returns for construction companies investing in research and development and innovation within that limited economy. Blockchain, however, is a distributed technology that can support small and scalable 'bottom up' innovation, and does not necessarily require the large scale investment associated with 'top down' innovation that is associated with significant cost and structural change.

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# resources.

## Websites

https://www.designinformatics.org/research_project/blockexchan

Design Informatics and Design In Action has created a workshop toolkit for anyone interested in exploring this rapidly developing new territory. Block Exchange is a fast-paced workshop activity that will open minds to alternative means of value exchange. Using Lego to simulate the Blockchain, participants will experiment with different ways of trading, starting from the basic acquisition of resources, through a fluctuating market and finally exploring peer-to-peer trading of value where anything goes!

https://ccegblockchain.com/

The CCEG Blockchain UN Lab focuses on the transaction of intangible and non-financial values using a unique combination of Blockchain Technology and the Social Earnings Ratio. Both represent the leading edge of current Fintech, Socialtech and Humtech innovations but combined they enable a new world of hitherto impossible mainstream interventions. Our work is open-source, collaborative, and ground-breaking. We focus on bringing structural change to intractable problems across all sectors.

https://hackernoon.com/last-night-a-distributed-cooperative-organiza-tion-saved-my-life-a-brief-introduction-to-discos-4u5cv2zmn

It stands for Distributed Cooperative Organizations, and it's a set of organisational tools and practices for groups of people who want to work together in a cooperative, commons-oriented, and feminist economic form. DisCO is also an alternative to another form called the Decentralized Autonomous Organizations, or DAO. If you're not familiar with DAOs, they are blockchain-based entities that can execute payments, levy penalties, and enforce terms and contracts without human interaction. Think of a virtual robot that can automate governance processes and execute investments and payments for an organization and you're on the right track.

https://www.rgu.ac.uk/news/220-news-2020/2765-technology-behind-bitcoin-used-in-a-first-for-architecture

Robert Gordon University (RGU) is leading an international team to launch the first-ever Decentralised Autonomous Organisation for architectural design by using blockchain technology commonly associated with cryptocurrencies like bitcoin.

https://trustlines.network/

Currently there are multiple issues limiting broad adoption of cryptocurrencies. They do not fit into the current economic reality where money is mainly created as debt by banks and the capital cost incurred when people provision cryptocurrencies is prohibitive. Moreover, the requirement of upfront deposit money, having a bank account, dependency on centralized, often non-regulated, cryptocurrency exchanges, lack of user-friendly user experience and the necessity to deal with cryptocurrency transfers are hindering adoption.

As a solution we offer the Trustlines Protocol — a decentralized, permissionless and open platform to host currency networks. The value in these currency networks is represented in IOUs (abbreviation for ‘I owe you’) issued by its participants. The design extends on the original Ripple idea with a strong focus on ease of adoption. The platform is designed in a way that there is no need to interact with any centralized services such as banks or exchanges. Besides, it comes complemented with a reference implementation of a mobile application.

# Reports

https://www.ahuri.edu.au/__data/assets/pdf_file/0019/26911/AHURI-Final-report-304-Understanding-the-disruptive-technology-ecosystem-in-Australian-urban-and-housing-contexts-a-roadmap.pdf

This report for the Australian Housing and Urban Research Institute (AHURI) on “Understanding the disruptive technology ecosystem in Australian urban and housing contexts: a roadmap” https://fibree.org/wp-content/uploads/2019/07/Fibree-Industry-Report-Digital.pdf

The FIBREE Industry Report is the most important yearly contribution of FIBREE to the market. It gives some in depth articles and a worldwide overview of the latest developments in the field of Blockchain and Real Estate.

https://www.ice.org.uk/ICEDevelopmentWebPortal/media/Documents/News/Blog/Blockchain-technology-in-Construction-2018-12-17.pdf

Throughout the world, the construction industry has long been challenged to improve its efficiency, productivity, and to embrace the opportunities presented by emerging technologies. This ICE insights report examines the potential of blockchain technology and asks how this disruptive technology could revolutionise the construction industry.

http://www.buildmagazine.org.nz/articles/show/what-blockchain-really-means

What blockchain really means — by Dr Dermott McMeel and Associate Professor Alex Sims.

# Podcasts

https://insureblocks.com/ep-86-real-estate-on-the-blockchain-insights-from-coadjute/

John Reynolds is the CEO and founder of Coadjute. John has a background in enterprise technology and helping organisations optimize internally. In this podcast he talks to us about the exciting blockchain opportunity they've unlocked in the real estate and construction industry which is worth $10 trillion globally!

https://insureblocks.com/ep-112-power-ledger-powering-energy-with-blockchain/

Dr. Jemma Green is the co-founder and chairman of Power Ledger. Power Ledger is a four year old technology company, with 20 power projects in over nine countries, that facilitate two things – the trading of electricity and the trading of environmental commodities using blockchain technology. In this podcast we discuss with Jemma how their platform is revolutionising the power industry and how it is being used to democratise power.

https://www.coindesk.com/podcasts/coindesks-money-reimagined/bermuda-david-burt-age-cbdcs

In this episode, Michael J. Casey and Sheila Warren of the World Economic Forum are joined by the newly reelected Premier of Bermuda, David Burt, who is spearheading projects to use the island as a testing ground for stablecoins and to launch a communally owned national digital bank.

## Videos

https://www.youtube.com/watch?v=mIvrLdZMVso

Understanding blockchain in 90 seconds.

## Technology demonstrators

https://www.youtube.com/watch?v=fX0NHUa3lNw&feature=youtu.be

Blockchain and BIM.

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chip of the new block(chain): a research project



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