Could blockchain replace the role of trust in the Construction Industry?

Marc Leddy

Master of Business Administration

National College of Ireland

Student Number: x19153104

Submitted to the National College of Ireland, August 2021

Could blockchain replace the role of trust in the Construction Industry?

Abstract

Blockchain technology is an innovative solution which uses a distributed ledger system to enhance traceability and transparency and improve data integrity. Integrating blockchain technology with existing technologies such as digital contracts and supply chain management software, allow for free-flowing data throughout a project. Blockchain has proven to be effective in the agricultural industry in financial transactions, logistical processes, and data management systems.

Evidence clearly suggests that blockchain technology has the ability to be adapted and implemented into the construction industry. The characteristics of the technology improve data integrity and reliability such that trusting the data will not be an issue. The only concerns remaining are, is trust an issue in the industry and considering previous research from McNamara and Sepasgozar (2020), can a technology be implemented successfully?

The research identifies some key literature highlighting concerns over ethical misconduct and failings in the industry. Mason (2009) states ethical misconduct can only be prevented by reducing the numbers of situations where contracted parties consider it necessary to seek an advantage at another's expense.

It is found that innovative technologies will likely be adapted by the industry once there are clear benefits. When a technology has distinct value propositions for the stakeholders involved, it is more likely to be embraced and implemented. The value proposition offered by blockchain technology is evident for all parties. However, the technology has been discussed and researched within the industry for quite some time without any successfully implementation to date.

Marc Leddy | x19153104 | MBA2

Declaration

National College of Ireland

Research Students Declaration Form
(Thesis/Author Declaration Form)

Name: Marc Leddy

Student Number: x19153104

Degree for which thesis is submitted: Master of Business Administration

Title of Thesis: Could blockchain replace the role of trust in the Construction Industry?

Date: 18 August 2021

Material submitted for award

A. I declare that this work submitted has been composed by myself. ☑

B. I declare that all verbatim extracts contained in the thesis have been distinguished by quotation marks and the sources of information specifically acknowledged. ☑

C. I agree to my thesis being deposited in the NCI Library online open access repository NORMA. ☑

D. *Either* *I declare that no material contained in the thesis has been used in any other submission for an academic award.
Or *I declare that the following material contained in the thesis formed part of a submission for the award of: Master of Business Administration ☑

Signature of research student:

Marc Leddy

Marc Leddy

18th August 2021

Acknowledgement

Could blockchain replace the role of trust in the Construction Industry?

Table of Contents

Marc Leddy | x19153104 | MBA2

List of Abbreviations

CTO	Chief Technology Officer
EMEA	Europe, Middle East, and Africa
EY	Ernst & Young
GMP	Guaranteed Maximum Price
IBM	International Business Machines Corporation
MSA	Master Service Agreement

Could blockchain replace the role of trust in the Construction Industry?

1. Introduction

It is common practice throughout the construction industry on large scale and mission-critical projects with complex designs to engage in 'open-book', 'cost-plus' or Guaranteed Maximum price (GMP) forms of contract with the supply chain. This provides both opportunities and risk mitigation on projects as it facilitates early engagement with the supply chain on projects prior to design development and co-ordination. Some of the main benefits of early engagement include the supply chain participating in design reviews, undertaking constructability/feasibility reports, and providing viable value engineering solutions.

Unfortunately, without a solid design, it is impossible to agree on a fixed price which will accurately reflect the final account of the project, hence the reason for 'open-book, 'cost-plus' and 'GMP' contracts. These contract types can prove very effective but only when used ethically and honestly which is impossible to assure as the client and therefore most clients rely on the integrity of their supply chain which is inappropriate for the industry which in 2019, was worth €30billion in Ireland. (Construction Sector Performance and Prospects 2019, 2019). A technology which could enforce data integrity, transparency and data validation would thrive in this multi trillion-dollar global industry.

Enterprise blockchain is a permissioned blockchain that can be used to streamline business processes at scale. It is not a public blockchain network so visibility of their data can be restricted to specific group (Hertig, 2021). It is used by corporations all over the world to track supply chain goods and/or settle global payments.

Some of the key features of blockchain technology which make it so successful include data integrity, decentralised technology, enhanced security (network is not regulated by a central authority which could manipulate the characteristics), distributed ledger and faster settlements.

According to the Government of Ireland, as published in the Build Construction Sector Performance and Prospects 2019, productivity in the €30billion industry between 2009 and 2016 remained stagnant suggesting a lack of innovation and engagement with new methods and forms of technology. As such, this suggests a potential pushback should a viable alternative to the existing solution be found.

Digitalisation in Construction has been an area of high interest for the past number of years with research studies including *Construction productivity and digitalisation: An*

Could blockchain replace the role of trust in the Construction Industry?

I.T. productivity paradox perspective' (Cidik, 2019), seeking to better understand how IT can improve productivity in construction and Manukyan and Papadonikolaki (2019), '*Digitalisation in construction: Mixed blessing for collaboration in projects*' which research leveraging digital technologies to further improve the effectiveness of collaboration on construction projects. However, McNamara and Sepasgozar (2020) conclude that on the contrary, inadequate research has been carried out around the process of technology adoption in the construction industry and the associated challenges. Unlocking this implementation technique would be a significant breakthrough worth billion in productivity to the global construction industry.

Lombardo (2020) writes that encouragement to engage and an improved user experience are key in enhancing the likelihood of engagement. Nonetheless, the stigma around technology still exists.

Digital contracts have been discussed as viable solutions in the industry for quite some time now but yet, case studies in industry are difficult to find. Digital contracts, known as smart contracts, are a digital twin of the traditional written form of contract which has the ability to automate the entire contract administration process of a construction project. The concern that remains is consistent with other automotive cloud-based technologies; How secure are they? Can we rely on them?

From a thousand feet, blockchain technology seems to have the answers but without a more in-depth research, it is difficult to draw a definite conclusion.

2. Literature Review

In order to provide the best context, all literature relating to blockchain integrated into the construction industry was considered extremely relevant. Other literature deemed relevant includes the adaption of the construction industry to other innovative products and processes and the integration of blockchain into other industries. The following Literature Review has been presented to best understand the construction industry in its present state including the challenges therein and deeper understanding of blockchain as it is currently applied to industries not limited to construction.

2.1. Current State

The traditional adversarial relationships between stakeholders often associated in the construction industry are becoming a thing of the past. A Study by Tan et al (2017) found that relationships between main contractors and their supply chain are becoming more important to the success of the project. Tan et al concludes that by maintaining a collaborative and partnering relationship between the two parties, it develops trust and mutual understanding which in turn provides mutual benefits. Both parties have different interests in the project but when these are fully understood and respected by each party, it creates a stronger relationship. Furthermore, the findings of this research reveal that strong relationships with supply chain are positively associated with main contractor competitiveness and prove advantageous in the medium-long term. A long-term partnering relationship is more likely to benefit both parties. If the relationships between main contractors and subcontractors are not properly managed, the performance of projects will be adversely affected (Tan et al, 2017).

Large pharmaceutical and technology companies and developers alike rely so heavily on seamless delivery within strict timelines and to a high standard of safety and quality. It is for that reason that they are choosing to engage in partnerships with their supply chain under Master Service Agreements (MSA). This has driven the demand for applying 'cost-plus and 'GMP' (Guaranteed Maximum price) contracts to align the interest of clients and contractors by creating a partnership for delivering programmes of works. Partnerships can provide significant benefits to the clients in terms of secured supply chain, early engagement from the construction supply chain specialists

and active participation in value engineering activities at an early stage. Black et al. (1999) concludes that overall clients are the greatest beneficiaries of this approach. Chan et al. (2011) challenges the risk profile of these procurement strategies and finds that the stakeholders are aligned on the impact of individual risks. Furthermore, they believe that the identification of the key risk factors and their relative significance is important in the risk management of target cost contracts and guaranteed maximum price projects, which, if properly done, would enhance the value for money throughout the whole procurement process. Benarroche (2020) states however that these models are a risk adverse solution for clients and rewards them efficient low-cost work through saving incentives. Surely this is only guaranteed through adequate incentives which could be considered a premium on the true 'cost of work'. The cost of work is defined by The Law Insider, a global contract database and resource centre, as:

"Cost of the Work means the direct costs necessarily incurred in the proper performance of the Work. Cost of the Work may include direct labour costs, subcontract costs, costs of materials and equipment incorporated in the completed Work, costs of other materials and equipment, temporary facilities, building permit fees, materials testing, and related items. Cost of the Work shall not include Construction Fee, general conditions fee, taxes, bonds, or insurance costs."

A GMP (Guaranteed Maximum price) approach is considered when there is usually inadequate design and or time to agree a fixed price. It allows the client to engage early with the contractor and a GMP price will be negotiated at such time when the project specifics are available. It can sometimes include a contingency factor for unknowns. The GMP is considered a 'not-to-exceed' and costs as defined in the contract agreement are reimbursed with a pre-agreed profit margin (Benarroche, 2021). Similarly, an 'open-book' approach follows the same re-imbursement method, but without the GMP cap.

On large scale mission-critical projects, an open book or GMP approach is often considered due to the flexibility benefits and timing associated with it (Levy, Thompson, and Wiest, 1963). Projects with extremely sensitive milestones are often referred to as mission-critical projects. This is due to the fact the project programme and project completion is driven by a critical path. Therefore, the project completion date is driven by a series of tasks and events within the project schedule. For example, you cannot put in the windows without the walls being complete first.

Marc Leddy | x19153104 | MBA2

Considering the extent of trust that is required to administer these large value GMP and cost-plus contracts on fast-track mission critical projects, it is no surprise that trust could be considered a risk and an opportunity for projects.

2.2. The Challenge of Trust

Leofwin Clarke, president of WDBC, identifies the four key principles of 'open-book' contracting as 'transparency and validation', 'accuracy and completeness', 'realism and fairness' and 'risk and opportunity assessment'. (Clarke, 2016)

Transparency in pricing is subjective. We can clearly calculate and validate the cost of employment and measure the quantity of material but the true time to excavate 3,000m3 or install 500m2 of ductwork is speculative. Therefore, we rely on trust and transparency. Furthermore, principles such as accuracy, fairness and risk also heavily rely on trust in the relationship between partners and therefore the challenge remains. The administration of these type of contracts relies on manual data entry and general administration to review and validate timesheets and invoices in order to process reimbursement under the contract. This laborious activity comes at a cost which some argue is unnecessary and overkill but also is a key stage for human error through large amounts manual data entry. An example of this could be seen in 'cost-plus' and 'GMP' contracts where invoices and timesheets are scheduled and processed for payment. Some projects could administer payments for tens of thousands of invoices and millions of hours of labour. As such, it is possible that errors are made in the manual administration and payment approval of this process. There also remains the question of what errors are intentional. Mason (2009) states that ethical improvements can only be delivered by reducing the numbers of situations where contracted parties consider it necessary to seek an advantage at someone else's expense.

Shah and Alotaibi (2018) summarises contractor unethical practices as under bidding, bid cutting and shopping, bid rigging and over billing. Cullen (2019) writes an article in the Irish Times that BAM, a contractor renowned for their ability to profiteer on contract claims, successfully underbid the National Children's Hospital project by 20% with the knowledge that they would not be replaced after they had completed the first section of the job. Shah and Alotaibi (2018) also found that the acceptance of bribes in the form of cash or gift and conflicts of interest are the most common forms of unethical practices. They conclude that the avoidance of conflicts of interest and encouragement

of the ethical practices will help to restore the investor confidence and improve the quality of buildings and infrastructures (Shah and Alotaibi, 2018). Adnan et al (2012) records the same findings but concludes that overstatement of capacity and qualifications to secure work, competitors' falsification of experience and qualifications and bureaucratic, government policy are also massive ethical issues in the current industry.

Traditionally, adversarial relationships are more common in the construction industry than meaningful trusting relationships. This is probably due to the lack of transparency in the industry and the perception that contractors take advantage of clients financially. The absence of trust in a relationship plays a major role in projects failing regardless of the delivery method which is irrelevant when creating a trusting environment on construction projects (Craig, 2020). Duane Craig also reports that the longer individuals work together, the better opportunity they have of building a deeper, lasting, trustful relationship. By its very tendering nature, bidding and awarding tends to create tension between participants causing another issue with developing and maintaining trust (Craig, 2020)

The Centre for Construction Innovation found that trust helps to make projects quicker and cheaper. Furthermore, their research concludes that risks can be mitigated when communications are trusted by all parties. Their research involved a deeper dive into the industry's business model which found that project teams are deployed on projects and relocated frequently depending on the project schedule and client expectations. This disrupted the trust and relationship building process.

2.3. Enterprise Blockchain

Blockchain is essentially a database technology which has proven to be a technological breakthrough in how digital information is stored, verified, and exchanged. (Essex, 2021). Enterprise blockchain is a type of permissioned blockchain that can be used to streamline business processes at scale. It is not a public blockchain network so visibility of their data can be restricted to specific group (Hertig, 2021)

Gandhi et al (2021) report that enterprise blockchains may be the answer to a number of supply chain problems. These includes issues common to many industries including traceability, trust, costly intermediaries, and low digitisation.

Could blockchain replace the role of trust in the Construction Industry?

Blockchain has the ability to provide a live, comprehensive, incorruptible data base of every detailed transaction across even the largest and most complex global supply chains. These transactions are not limited to financial transactions. For example, IBM blockchain's Food Trust network was leveraged by Walmart to determine food products that needed to be recalled and Microsoft's partnership with Ernst & Young (EY) to use Ethereum blockchain for gaming royalties. Furthermore, blockchains can eliminate the concern of mistrust in relation to the interactions of supply chains.

There is no doubt that this is a technology which is continuing to develop and grow on its path to maturity. In a 2020 Forbes article, Richard Brown, CTO of R3 (a leading provider of enterprise blockchain technology), wrote that since the creation of blockchain, there have been many successes in the space which has been boosted amidst the pandemic-related challenges being faced by all businesses. Brown (2017) also states that blockchain thrives on providing accurate, timely and secure data sharing between firms and relying on market-level cooperation.

Rasmus Molberg (2020), states that in a world with modern businesses, there are siloed repositories for data as each organisation keeps a separate copy of their data because there is no collective trust. Not only does this place companies at a data security risk. It is severely wasteful and inefficient. Organisations are individually retaining a central repository which does not communicate or reconcile with the information retained by other organisations.

In a research report carried out by Wageningen university and research, a number of key technical choices for blockchain technology are identified. These are namely, Permission design, i.e., whether permission is needed to access the blockchain; Choice of consensus algorithm, i.e., how a new block is added to the blockchain; whether or not to use smart contract, i.e., whether to use the blockchain as a virtual machine where programs representing business processes are run; Whether or not to use cryptocurrency, i.e., whether the consensus algorithm and smart contract operations depend on an artificial currency or not (Ge et al, 2017). This report also concludes that blockchain is not solution to all problems as it does not necessarily outperform existing systems. Blockchains cannot store as much data as some expect. It merely refers to databases. And finally, the mechanics of the technology are still not fully understood by stakeholders and which restricts their ability to full embrace it and adopt the innovative technology.

2.4. Adoption

A significant amount of research is ongoing on the general topic of digitalisation in the construction industry including blockchain. McNamara and Sepasgozar (2020) conclude that insufficient research has progressed around the identification of contributing factors that will influence successful adoption of technologies in the industry. Some of these studies include Cidik (2019), *'Construction productivity and digitalisation: An I.T. productivity paradox perspective'* seeking to better understand how IT can improve productivity in construction and Manukyan and Papadonikolaki (2019), '*Digitalisation in construction: Mixed blessing for collaboration in projects*' which research leveraging digital technologies to further improve the effectiveness of collaboration on construction projects.

McNamara (2019) offers the opinion that the technological state of the construction industry is inadequate and as such the cost of implementing blockchain is likely to be costly. These costs would include investments in software, training, and downtime for system migration. Ellis (2020) concludes that the obstacle for implementation sits with the lack of adequate resources in the industry to operate a complex system such as blockchain which is linked to the fact that the majority of industries are typically more traditional and less organised. This could require significant levels of training or outsourcing of system management.

Both views are reasonable, historically it is no secret that the industry has been typically slow at adopting new technologies and resistant to change such that it is possible that the market is just not ready. Perhaps the industry needs time to mature until the idea of blockchain becomes more of a reality than a dream. Lombardo (2020) concludes that construction companies who see the highest success of technology adaption start with a bottom-up approach. Encouraging engagement and improving user experience create operational shortcuts and fix processes (Lombardo, 2020).

The application of blockchain technology in any industry will not be easy. Even for technically advanced people, its technical underpinnings and their practical implications are difficult to grasp. The concepts of blockchain include consensus algorithms, hashing and distributed ledgers. These phrases are not technical details and should be understood be all stakeholders determining whether blockchain should be considered and for what applications. Without understanding these phrases, it is not possible to determine the most efficient and effective way of incorporating blockchain into a business workflow.

Widespread adoption is a slow process. As with any emerging technology, it takes time for industries to adapt and integrate new systems with existing infrastructure (Brown 2021).

2.5. Smart Contracts

Intelligent contracts ('iContracts') are computer protocols that facilitate, verify and enforce the negotiation and performance of a contract, or that remove the need for a contractual clause. Traditional human administration would be minimal with the implementation of these contracts which would prove to be truly autonomous. (McNamara, 2020) This innovative technology solution of embedding the contractual terms and conditions into a digital entity is a complete contrast to the traditional paper copy solution which is common practise of projects all over the world. By digitalising the contract, we transform it from a tool only used in dispute to a masterplan contract process enforcing contract terms including payment protection, insurance, and data protection. Blockchain has proven benefits of increasing security and creating traceable payment information.

Utilising blockchain technology, an iContract could be considered a robust solution to add transparency to every transaction of a project. Furthermore, transactions through blockchain can stabilise cash flow for all parties including the client, main contractor, subcontractors, and suppliers. (McNamara, 2019). Many subcontracts throughout the industry often include a payment clause which provides the main contractor adequate time to receive funds from their client and process payments to their supply chain. This is known as 'pay-when-paid'. (Viator, 2020) Unfortunately for subcontractors and suppliers, this can mean payment terms in excess of sixty days in some instances. Using blockchain, this payment process from client to main contractor, subcontractor to supplier could be in the same day with each party receiving their relevant profit fee. Furthermore, the transparency ensures that should a party become liquidated at any stage, that assurances are in place to ensure the supply chain have been paid with relevant funds and therefore possibly protecting the project.

Building Information Modelling (BIM) is one form of technology already embraced by the industry but relies on peer-to-peer networks for information sharing. (Ellis, 2020) Grace Ellis (2020) believes that through further adaption of BIM and migration of BIM

and blockchain, updates can be displayed in real time which would improve communication and transparency across the project.

It is important to note that smart contracts do not rely on blockchain, nor does blockchain rely on smart contracts. However, the management and control of a digital smart contract would be enhanced with the integration of blockchain technology. Once a control is outlined digitally, the blockchain technology can store and monitor the data securely and ensure the contract is administered effectively and efficiently, especially in relation to liabilities and payments. This refers to liabilities of a party under the contract that must be fulfilled e.g., delays or damages.

2.6. Agricultural Industry

Blockchain has been used as a solution to problems in other industries. One such industry where blockchain has proven to be an effective solution is the agricultural industry where it is being applied for improving food safety, and transaction times (Bermeo-Almeida et al, 2018).

In 2017, a report was written by Ge et al (2017) to better understand the implication of blockchain technology on the agricultural industry. Specifically, the report analysed the impact blockchain has had on supply chain management and agri-food chains. The report concludes the added value of blockchain technology over traditional IT solutions is that blockchain can be used to ensure that all stakeholders share the same tamper-proof information on the validity and provenance of certificates. Furthermore, the report finds that most SMEs are too small or lack the expertise to invest in blockchain technology themselves. The suitability of blockchain technology on the industry is therefore being assessed on an individual basis (Ge et al, 2018).

The Global Trade magazine published an in-depth article in partnership with EKA software solution experts in March 2021 on the benefit analysis of blockchain in agriculture. The distributed ledger enables transparency and clarity and ensures that every party involved in the data sharing has the same information which provides for transparent transactions and eliminates conflicting information (EKA, 2021). This transparency improves communication and could eliminate 'middle-men' allowing suppliers to deal directly with retailers which in turn could improve product quality and order fulfilment resulting in increased sales for both parties. EKA (2021) concludes that blockchain in agricultural as it is currently understood is just the tip of the iceberg

and the possibilities of smart farming and other data-driven innovations which could transform the industry are not fully understood.

Another example of effective use of blockchain technology in agriculture is reported by Haylee Sok (2019) as she investigated the impact of 'Grain Discovery' a new blockchain platform using the technology to connect farmers and buyers. Sok found that the platform has helped reduce wasted grains as it quickly identified new buyers requesting a transaction for the farmer. Furthermore, it allowed farmers to engage with new buyers locally, reducing the logistically costs and increasing margins for both the farmer and buyer. This was all benefited from the transparent and verification characteristics of the blockchain platform (Sok 2019).

2.7. Interim Conclusion

Based on secondary findings, it is concluded that there is strong evidence of the effectiveness of blockchain since the technology developed. Over this period the technology has developed but it is still not fully understood or appreciated which has led to a slower uptake than original anticipated. This slow adoption is also impacted by the construction industry and their Laggard type approach. Perhaps when blockchain technology has further developed in the agricultural industry and digital currency becomes more commonly used, blockchain technology will be fully appreciated by construction professionals.

The agricultural industry has definitely started to reap the rewards of the clear benefits on offer, but it is also noted that it has much more development potential which will natural progress as with all technologies.

As the world becomes paperless and businesses operate digitally whilst trying to reduce their carbon footprint, smart contracts will become a key focus in the construction industry. Although not necessary, a key function to the success of smart contracts is blockchain technology. It is evident that blockchain has huge benefits, but can they be utilised effectively in the construction industry or is it the case of a solution looking for a problem?

3. Aims of research

The primary aim of the research is to investigate further if the fundamentals of blockchain can assist in creating a more transparent environment in the construction industry. Blockchain is commonly associated with crypto currencies and there are proven benefits such as record-keeping, transparency, and verification, assisting with the administration of payments between clients, contractors, and suppliers. Similarly, could this transparency and ledger style format encourage the supply chain to act with increased ethical standards or is there a risk that blockchain payments could instigate laundering as is experienced with cryptocurrencies through blockchain.

It is evident from reviewing literature that the implementation of blockchain can offer other benefits beyond payment processing which it is more commonly associated with. iContracts which is currently being heavily researched could prove to be a game changer in the industry in years to come. If we move away from the traditional paper copy of the thirty-six standard RIAI form of contract clauses and convert them to a workflow hosted and automated through blockchain then opportunities could be endless.

The final question remains, is the implementation of these and any other forms of digitalisation possible in the construction industry at present and if so, how? It is evident that the majority of the industry would be considered laggards rather than innovators or adaptors as defined by Rogers (1983), and as such what is the solution to driving long needed innovative technology in the industry.

4. Methodology

A research methodology strategy was drafted as part of the initial research study. This was reviewed and critiqued on numerous occasions prior to commencement of the research study. This forms the basis of the following methodology with updates made for considerations to the actual research method carried out.

4.1. Overall Approach

The most suitable approach to this research proposal was qualitative to enable the researcher to discover ideas using the exploratory aspect of qualitative research. This involved interviewing small samples of cohorts on video calls. This would have preferably been done in a natural setting which due to Government pandemic guidelines was not viable.

Qualitative was identified as the best and most appropriate approach given that the topic of this research is very specific and specialised. Blockchain is a relatively new technology which has not been fully established in many industries including the Construction industry which forms part of this study. Consequently, the demographic of suitable interviewees was small and given that qualitative research is conducted among smaller groups, it was ideal for researching with key informants. Qualitative research helped the researcher gain a more in-depth understanding of the research as the open-ended questions facilitated unprompted response. On the contrary, it is very important to select the right type of qualitative research to ensure the objective of the research is accomplished.

Quantitative research was considered but given its measurement and numerical characteristics was not considered appropriate for the aim of research and category of questions it was hoping to answer. Quantitative research provides statistically robust results but won't provide an understanding of why or how. Pursuing statistical relationships can prevent the researcher from focusing on research themes and their relationships which could be hugely beneficial to the research. The researcher therefore believed that quantitative research was not an appropriate approach for this study.

Experimental research was also considered by the researcher. Experimental research is carrying out an experiment by manipulating one or more independent variables and measuring their effect on one or more dependent variables. This procedure tests a

hypothesis. Experimental research could have been combined with another form of research to effectively carry out research on the topic however due to time and budget constraints, it was not considered a viable approach.

The qualitative research approach was then considered. This included considering focus groups, interviews, and an ethnographic method. Th ethnographic method allows the researcher to really understand the problem and consequently derive a better solution (Logan,2020). The strengths of ethnographic research are its ability to identify and analyse unexpected issues. Given that this research aims to test a hypothesis, this method is not deemed the correct approach by the researcher. Interviews are a very common approach and have the ability to ask specific questions surrounding the topic of the research to a small specialist cohort, it seemed ideal. It also allows the researcher/interviewer to consider the nonverbal behaviour of the respondent. Due to the smaller pool of research participants, interviewee selection is vital to the success and accuracy of the research (Kennedy and Montgomery, 2018). Focus groups were also considered both as a replacement for the interview method and as a supplement but given the difficulty in organising a convenient time for professionals across multiple time zones, it was not viable.

4.2. Research methods

In anticipation for the interviews, the preparation of the interview questions and participation selection is extremely important. Questions should be drafted based on findings from the literature review and strategically linked to the primary and secondary research questions. The agenda for the interview will be developed and shared with interviewees in advance to allow them to prepare. However, specific questions will also be strategically prepared but not shared and used as necessary to ensure the greatest value from the conversation. The questions were developed based on the themes identified from carrying out the literature review. These themes include the beneficial characteristics of blockchain, impact of blockchain technology on supply chain mechanisms, blockchain technology resource allocation, implementation challenges, Ethical misconduct in the construction industry, and digital contracts. It is acceptable that the interview may progress beyond the boundaries of the agenda to get a full range a depth of information on the research topic.

It is important throughout the interviews not to discuss any detail which could compromise the interviewee, such as the sharing of specific contractual, financial, or other sensitive information. Furthermore, it was ensured that questions did not challenge the integrity of the interviewees or companies when discussing the topic of ethical standards within the construction industry. The interviews were carried out on research category A participants (little ethical risk). The researcher has read and understands the Ethical Guidelines and Procedures for Research involving Human Participants.

Five interviewees were selected based on their experience and knowledge of the topic but not necessarily experience in the construction industry as to not to limit the potential to explore the opportunity associated with the research topic. A further three participants failed to respond to the researcher's invitation. Unfortunately, their reason for failure to participate is not known. There can be plenty of reasons; a respondent may feel the topic is a waste of time, that they cannot adequately contribute or perhaps their own commitments at that time do not permit them to participate.

In order to achieve the greatest value from the interviews, it is important that the researcher/interviewer is intimately involved and directing the interview meaningfully. Other qualitative research methods which could prove useful are documentation review to get a comprehensive understanding of historical information to better understand the problems that exist and possibly to carry out case studies to understand in depth the clients experience using existing methods (Kennedy and Montgomery, 2018).

A Pilot Study will not be undertaken in this research. The sample of potential interviewees with relevant experience and knowledge is too small to achieve any significant benefit from a pilot study.

4.3. Research Details

At the time of defining the research strategy, the researcher decided that the total number of participants should be five or six. This was determined by the specialism of the research topic and the total number of potential participants.

The first interview took place on Sunday 25th July via phone call with 'Participant 1'. Participant 1 was identified as a key figure in the blockchain technology space. Having recently graduated with an MSc. from University College Dublin Business School, and

lectures at Trinity College Dublin to MBA and MSc groups. Participant 1 is a director with BNY Mellon and holds the role of EMEA digital assets and blockchain lead. Blockchain Ireland was founded in late 2015 by Participant 1 and group of likeminded professionals with the aim promoting blockchain technology in Ireland. Participant 1 now holds the role of advisory board member. He does not have any construction industry experience.

On Monday 26th July, the interview with Participant 2, founder, and CEO of a technology start-up took place. Participant 1 was originally from Atlanta, the capital U.S. state of Georgia but in 2018, moved with his family to California to take his newly founded technology start up to the next level. Their company is product build on blockchain technology and developed for use in Construction industry to securely pay supply chain quickly in a transparent environment. Participant 2 is also the founder and CEO of a construction industry e-commerce platform built on blockchain technology.

Participant 3, CEO of digital supply chain management platform and founder of Construction Blockchain Ireland, was the third participant identified. Participant 3 resides in Dublin and holds qualifications from Technological University Dublin, Trinity College Dublin and most recently University College Dublin. Their platform is a technology start up, built on blockchain technology aimed at accessing, evaluating, monitoring, and analysing managing and controlling supply chain in the construction industry.

Participant 4, an experienced construction professional with a speciality in digital engineering participated in an interview on Friday 30th July. Based out of Australia, their current role is to introduce emerging digital engineering technologies to leading construction contractors and consultancies. They pride himself on enabling clients to maximise the value of connected data.

The final interview took place on Saturday 31st July with Participant 5. They are founder and CEO of two innovative software products specifically for the construction market. A guest lecture at Technological University Dublin, they have a passion for digital disruption and construction technologies including the impact of blockchain technology on the industry.

4.4. Analysis Technique

The researcher analysed the research data using the six phases of thematic analysis technique (Braun & Clarke, 2008) which is considered an effective approach for analysing data attained through qualitative research. The first stage of this technique is common to all forms of qualitative analysis and involves the researcher familiarising themselves with the data by reviewing it repetitively and noting any analytic observation.

Secondly, the researcher assigned preliminary codes to the content considered important to the research. Preliminary coding is the method of applying a numerical code to each statement made by the interviewee. These codes were then assigned to a relevant theme. The themes were initially outlaid following the findings from the literature review, but they developed following a deeper analysis of the coding. The coding of these important features of data is an analytic process and should consider both a semantic and conceptual understanding of the data.

The third step required the researcher to search for patterns across the range of interviews using the coded data defined in the previous step. Braun and Clarke (2008) explain this step as comparing the codes as bricks and tiles and this step requires the researcher to build walls and roofs. It was extremely important that the researcher took due care to identify patterns were shown and identify all data relevant to each theme. The next stage was reviewing the themes and checking it against the associated data to ensure each theme was robust. This sometimes resulted in sub-splitting themes or merging themes for a better result. Cross examining the relationship of themes was necessary to achieve this and also to better understand any relationship between themes.

During the fifth step, the researcher produced a detailed analysis. Braun and Clarke (2008) also deem it necessary to construct a concise punchy and informative name for each theme. Producing the report was the final step of the six-phase thematic analysis. It was very important to weave together the analytic narrative and provide a persuasive argument with consideration for existing literature.

Other analytic techniques were also considered for this research methodology. In the first instance methods used for analysing quantitative data such as regression analysis, linear programming and data mining were disregarded. There were however a number of analytic techniques appropriate for qualitative data which were considered before the thematic technique was decided upon.

Qualitative Content analysis was not chosen at it was deemed time consumed and not very effective with the potential of losing important nuances in communication. The narrative analysis and discourse analysis were both considered inappropriate for the aim of the research.

4.5. Research Tools and Materials

The tools required for this research methodology were minimal given the choice of approach for conducting, collecting, and analysing the data. None of the participants were known personally to the researcher before the interviews started. As such, the researcher arranged some introductions through LinkedIn social media platform or through a contact of mutual acquaintance. At that stage, email correspondence began discussing further detail on the study and a consent form was shared and returned signed. With the world in the middle of a pandemic, it was not possible, nor appropriate to arrange an interview meeting in person for even the most local participants. Instead, Interviews were arranged using Microsoft Teams and Zoom platforms.

The researcher has reasonable IT skills which allowed them to use Microsoft excel and Power BI for organising and identifying even the simplest of analytical review

4.6. Research Challenges

It is very seldom that research is conducted without obstacles. It is how the researcher overcomes these challenges that defines the success and quality of the research conclusion. Some of the challenges faced by the researcher are outlined below.

The challenge of communicating on different time zones was difficult from the outset. It was difficult to maintain constant contact with the participant from the initial stage as every message including initial introductory messages took almost 24hours to respond. Time zones for participants ranged from Greenwich Mean Time -8 to Greenwich Mean Time +8. Nonetheless, with perseverance, calls were arranged at a time convenient to the participant during early morning or evening local times.

The researcher has ample experience in an interview setting and is comfortable controlling a conversation. The interviews as part of this study were different as the topic of conversation was very specialised and the researcher has identified these participants as subject matter experts. Consequently, the researcher could not help but feel intimidated and uncomfortable at times discussing a technical subject with

such experts. The researcher assured themselves that they had done adequate research on the topic and in turn successfully conducted the interviews.

During one specific interview, one participant had to drop off the call unexpectedly halfway through the call. This caused an inconvenience, but the researcher organised themselves and waited until the participant was available to re-join moments later.

During another interview, one participant continued to digress from the research questions. Whilst the conversation was somewhat relatable and interesting, in the interest and respect for each other's time, the researcher re-focused the interview on the research questions.

The professionals involved in this research were extremely generous to provide participate and share their knowledge and time. Nonetheless their time is precious. It was highlighted in advance by some of them that their would-be time constraints and they were limited to the time frame they could comment. The researcher took a proactive approach and developed a time management plan to ensure all questions/topics were covered adequately throughout the call.

An important aspect of the research study was the ethical standards of the construction industry and as such it was important not to discuss any detail which could compromise a participant. These were discussed at an early stage, in advance of interview arrangement.

4.7. Methodology Evaluation

A Qualitative research method was selected, and although the researcher personally enjoys quantitative more, qualitative was definitely the best method for ensuring the success of the study. The interviews were very successful and a great choice for attaining an in-depth perspective of the research questions. The researcher maintains that a smaller number of five participants is the optimum quantity. It provides a broad range of views, but the small cohort ensures the participants are all subject matter experts and not just professionals with a part-time interest in the topic. The researcher feels had there been a requirement for more participants that the quality of same would be compromised. On reflection, the researcher would have really enjoyed the potential discussion and outcome from a focus group. However, in the current climate and given the specialism of the topic, it was not a viable method.

Qualitative research data analysis can be time consuming and often difficult to decipher and compare. However, the analysis technique worked really well considering out the research data was collected. It allowed the researcher to create links between the interviewee's responses to challenge/support the hypothesis.

It was unfortunate that all interviews were held online but it is understood by the researcher the necessity of this and the importance of compliance with government guidelines.

5. Analysis and Findings

The six phases of the thematic analysis technique were used to analyse, dissect, organise, and review the data gathered from the qualitative research. The five interviews conducted by the researcher provided significant insights and valuable opinions from key professionals and stakeholders in the construction industry.

As part of the thematic analysis, the data has been summarised in under six key themes as follows:

1. Ethical Perception
2. Blockchain Benefits
3. Supply Chain Management
4. Implementation
5. Industry Adoption
6. The Smart Relationship

5.1. Ethical Perception

A common theme throughout the interviews was the perception of ethical standards that exist in the industry. The discussions surrounding ethical standards were always going to be a sensitive topic. Evidence surrounding ethical misconduct is usually secondary information (word-of-mouth) and thus without proof, nobody wants to be accused of defamation especially when without the necessary evidence to back up the claim. Consequently, prior to the interviews, the participants were advised they were not obliged to respond to the question related to ethical standards and should they choose to answer that no specific details should or would be referenced. 80% of participants provided an opinion on this topic which feeds into the first theme of the research findings, ethical perception.

Participant 4, stated strongly, *"the industry is rife with corruption and ethical failings. Not necessarily major corruption but there is a major issue in the industry which is driving the cost of construction projects up"*. Furthermore, participant 1 stated, *"the industry in Ireland is so small and relationships can be too good between key business leaders. This leads to issues when it comes to contractor and contractor ethical standards and contractor and client standards"*. This suggests collusion between contractors to ensure that projects remain profitable during the tender periods. The participant is furthermore suggesting

that relationship in the Irish industry is having a negative effect on the ethical standards of same.

Participant 5 states, *"At the end of the day, it has a negative effect on our industry both from the poor perception of the industry but also because it drives the cost of construction up which will in turn affect the output and value for investors, developers and public bodies."* They feel very strongly about the impact that ethical misconduct is having on further investment into the industry and wider economy.

Participant 3 agreed. *"The construction sector in Ireland is known for its wheeling and dealing. Everyone knows it (ethical misconduct) goes on, but it is very difficult to prove.", "There is an issue around trust with supply chains. There is no regulator and therefore there is tons of information that has to be taken at face value".* Participant 3 response, which echoed that of both 4 and 5, suggests that supply chains are sole cause of any misconduct. There does not seem to be any blame or fault attributable to the client or their representatives.

Participant 2 stated *"you would be naive if you thought every industry in every market (country) was squeaky clean"*, *"Insofar as the construction industry, yes I think the standards are acceptable"*

Participants 2 and 5 were both satisfied that ethical standards were acceptable to the extent of their experience. Coincidently, both professionals are based in different markets operating from United States of America and Australia. Their views contrast those of participants 4 and 5 who have experience in the Irish market.

Participant 1 did not comment on this theme as they do not have experience in the industry to form a justified opinion.

5.2. Blockchain Benefits

The researcher identified a theme of benefits surrounding blockchain technology. The findings from the interviews and the literature review research were consistent when considering the benefits of blockchain. Although the participants provided a more insightful and detailed summary based on their experience and research. Providing better accuracy, more transparency and data security are some of the benefits to its users to name a few. Gandhi et al (2021) summarised these quite well stating that blockchain technology offers solutions to traceability, trust, costly intermediaries, and low digitisation.

Participant 1 elaborates *"It offers you an opportunity to develop new operating models with an underlying infrastructure and overlaid services which can be provided in a very different way, a more efficient way"*, *"the potential is there to explore tokenisation, fractional ownership, and programmability and mobility of tokens"*.

Participant 2 states *"The characteristics of blockchain optimise business processes, by developing a common immutable ledger shared across organisational boundaries.*

Participant 3 states *"Blockchain will be a very good solution in theory for enabling information to be more trustable and more verifiable.", "I have been discussing and monitoring the progress of blockchain in the industry for six years and I couldn't tell you one live solution out there that has any impact on people companies or systems. Blockchain might be lots of things but to be honest, I don't think it is going integrate and innovate the industry any time soon."* This is significant information, such that considering the evident benefits, the technology has provided little or no impact on the industry to date. This will need to be discussed further.

Participant 5 states *"I am a massive fan of blockchain technology because it offers benefits such as data driven, objective, commercial engagements"*, *"it removes the concerns of security of our data for asset and project owners and also has the strength of enhancing data integrity"*

5.3. Supply Chain Management

The interview participants were questioned on the impact blockchain technology could have on supply chain mechanisms which developed strong findings on supply chain management which the researcher has categorised as a theme. It has been highlighted from the literature review research that Agricultural industry has already tested the technology with Ge et al (2017) concluding that the technology offers the added value that it can be used to ensure that all stakeholders share the same tamper-proof information on the validity and provenance of certificates.

Participant 1 states *"In terms of ownership of the asset, an immutable register as to who own expensive machinery, materials and equipment offers a couple of benefits"*, *"irrefutable record that I have transferred an asset to you, and you*

can reference that ownership instantly, but we also have the benefits of digitalising the associated documentation with that transfer of ownership and the financial aspect of it too" They strongly believe that transfer of assets and associated documentation can be easily processed using blockchain technology.

Participant 2 states *"A single project could have anywhere between 50-100 different organisations involved. That's a lot of transactions and I don't just mean financial transactions, transactions of materials also. Now what if we could digitise and automate that and then control the reliability of the data. That is why blockchain technology will evolve supply chain management aspect of the industry."* Participant 2 echoes the response made by Participant 1. They also emphasise the impact of automating and improving the ingratiation of project data and stakeholder communication

Participant 3 states *"Supply chain Management is complex in any industry. They are particularly complex and particularly fluid in the construction industry.* Projects, especially those managed with and agile approach, can be extremely unpredictable and as such, automation, and reliability of information as suggested by participant 3 is very beneficial to supply chain management.

Participant 4 states *"I think material management is a great idea. It doesn't matter what data or aspect of the project we look to transact or transfer, blockchain technology opens up objectivity and transparencies"* Participant 4 concludes that blockchain technology is an effective solution for managing an asset, material or otherwise.

5.4. Implementation

The researcher identified 'Implementation' has the fourth theme of this research. There has been a trend of findings related to the implementation of smart contract and blockchain technology into the construction industry.

Participant 2 states *"Traditional construction processes can be followed. The project is still defined in the same way in terms of contract and programme. Construction project managers still have the same approvals, the contractor still has the same authorities. They only difference is its controlled and verified on the blockchain. When tasks become digitalises, the constraints of doing something at a granular level are no longer imposed on the process"*

Participant 5 states *"In reality, blockchain relies on data to be effective and it cannot manage data successfully, if the data is not available and accurate at the start. This means companies need to invest in digitalising generally and data entry. They typically handover an asset of project in stages, based on the commissioning plan and because of that, they do need to go down to a more granular level and possible down to tag level on all plant for the benefit of operational lifecycle asset management", "I think we already have the professionals in the industry than can manage this, it is just about changing the mindset from this is my IP to a more open source style environment which is fully open and transparent which some contractors will probably not be happy with"*

Participant 4 states *"It really comes down to that optimum level of efficiency and effectiveness. In reality, using the example of the steel work in a building, I don't think its efficient of effective to manage that contract down to the mark number or piece number. We need to find a reasonable approach, otherwise the cost of implementation will outweigh the benefits"* McNamara (2019) concludes that the cost of implementing blockchain will outweigh benefits in any case due to the construction industry inability to adapt technologies in the past such that training costs, downtime for system migration and software costs will outweigh the associated benefits.

5.5. Industry Adaption

The 'Industry Adaption' theme relating to the challenges faced to date in relation to the adaption of technologies in the construction industry and the strategies to overcome it have been summarised in this theme.

Participant 1 states *"A lot of companies and industries have been built over decades and centuries, a new technology comes along, an infrastructural network technology, and you simply just can't throw one system out and start another", "You need to slowly decommission and migrate to another and that doesn't happen overnight. It takes significant investment over many years", "It is the opposite of a quick win and executives need to realise this is something that will happen over a 5-year time frame rather than a twelve or twenty-four-month timeframe, Some executives might not even be in a job for five year"*

Participant 2 states *"The construction industry has reached an inflection point where the legacy processes and methodologies are going to be replaced with a much more efficient and process driven platform.", "If we ask a contractor, do you want to get paid quicker, do you want us to save you time and money, they will buy into a technology, simple. Stakeholders need to see a really compelling value proposition"*

Participant 3 states *"In order for any technology to be a success, everyone needs to buy into it. Blockchain provides a shared database of reliable information but essential it is useless data if its people don't buy into it and trust it. If you could build in a level of trust, that was leveraging blockchain, that would be a significant benefit to the industry", "the real problem for technology adaption in construction is not the people, it's that the value proposition for the technology has to provide real value for all the stakeholders. The value proposition is different is different for the client, the main contractor, and the subcontractor. and the supply chain. The first question they want to know is, what's in it for me."*

Participant 4 states *"how many contracts get to 98% complete and then it takes 20% of the time to complete the last 2%, this a common strategy for contractors in the industry to front load cash. Now if we try to introduce a technology that makes everything more transparent, why would these contractors engage? They won't and if they have to then it's going come at a premium.", "We have seen during the implementation of Building Information Modelling in the industry as more and more responsibility comes on the contractor for correctly modelling and co-ordinating the design before, during and after construction, this creates a risk in their opinion and contractors price risk. Potentially all the benefits of implementing Building information Management have been outweighed by these premiums we are paying. Similarly, if we remove their opportunities be making the environment more transparent, I suspect they will price that too."*

Participant 5 states *"Our failure to adapt to new technologies in the past can't just be because of the attitude of older individuals"," The technology industry have made a mess of it and made it very difficult for industries like construction to adapt. They have overcomplicated the interoperability of different data sets creating confusion for contractors on what to do and what to trust. It has created*

a horrible wash of uncertainty and integrity of data.", "Innovation is only created through necessity. There is no need to innovate through a discretionary fund based on something that looks fun or looks interesting. That's just the reality of it. If something is business value driven and is actually adding some sort of cost or time benefit then it will be adopted. If its intuitive and interactive, it will be naturally, organically adopted." "We just need to start understanding who is going to accept it and perhaps it needs to be mandated by public bodies or private companies", "the data has to drive the outcome more so than the person themselves. As such, companies will need to change their business model"

The findings are quite consistent such that they suggest that industry's adoption of a technology will be likely to encounter challenges and restrictions. This is expected considering the findings from the research carried out by McNamara and Sepasgozar (2020) in relation to the construction industry's inability to implement innovative technologies. It also fair to expect this considering that Participant 3 highlighted that blockchain has not yet successfully provided a tool that impacts the industry despite the research.

5.6. The Smart Relationship

The discussion of blockchain technology and their strong and influential relationship with Smart Contract technology created the final theme identified by the researcher. The benefit of smart contract technology and its dependency on blockchain technology were key points of discussions during the interviews.

Participant 2 states *"Smart contract technology digitises the contract administration and provides undoubted efficiencies for everyone involved. The contract, entered in computer code, creates a digital twin which can be automated with ease.*

Participant 3 states *"Smart Contracts are simply digitalised versions of the traditional written contracts covering payments clauses, liability clauses, notice periods. This is process is practically useless unless it is managed and regulated correctly. We digitalise it because we want to automate it, but if we need to manage it manually, it defeats the purpose. That's where blockchain enhances the situation. The simple blockchain ledger regulates the smart*

contract and provides the validity control which will drive smart contracts to success in the near future.

Participant 4 states *"Smart contracts and blockchain technology come hand in hand. We can't implement the automation of contract administration without a level of control and integrity. Blockchain technology is what compliments smart contracts. If smart contracts were pancakes, then blockchain would be the maple syrup."*

Participant 5 states *"I think smart contracts are amazing, the idea that we can digitalise all of this paperwork and make processes such as contractual engagements and payments so much less ambiguous and liability in some respects as well"*, *"the exchange of contract requirements or acceptance of a deliverable is linked to a digital twin, such than if something is delivered or completed and there has been acceptance based on the data that is connecting the two parties together, then theoretically, the client should not have a subjective view over an approved payment".*

6. Discussions

The above summarised themes are discussed below. Research carried in the Literature Review is also considered in this section where relevant to better assist with the final conclusion.

6.1. Ethical Perception

The conclusion of the standards of ethical practices in the construction industry will define whether trust is in fact the issue and or the problem, if it is in fact also concluded that blockchain technology is a solution.

It is evident from the participants answers that there is a different perception of ethical standards between those working in Ireland and those coincidently outside of the EMEA (Europe, Middle East and African) region.

Although the specifics around what ethical improvements could be made, it is evident that the perception in the Irish construction industry is that there is room for improvement. The extent of what improvement is difficult to measure but it is necessary to improve the perception of those both within and possibly outside of the industry.

However, it was found from the interviews that the relationships between key stakeholders in the industry encourages potential misconduct. Ireland is a small region and as such, it would be reasonable to expect that with the natural turnover of employees, professionals would move between roles with clients/developers, main contractors, and subcontractors throughout their career. Some research during the literature review conflicts these findings as Craig (2020) suggests that the building of deeper lasting relationships builds trust and prevents ethical misconduct. This could be true to an extent, although it is difficult to argue against Mason (2009) who believes that ethical misconduct can only be prevented by reducing the numbers of situations where contracted parties consider it necessary to seek an advantage at another's expense.

One major issue this presents, as highlighted by one of the participants, is the available funds to invest into infrastructure by both the public and private sectors. If ethical misconduct exists, this presents a huge impact on the ability of developers, investors, and public bodies alike to build more houses, upgrade and expand public transport and become a more affordable solution for foreign investment. Theoretically, if ethical

misconduct inflates construction costs by 20%, then 20% less infrastructure investments can be made. Similarly, project cost inflations can also lead to the viability and profitability not allowing some projects to proceed.

It is also noted although 100% of participants with construction professional experience agreed that standards were below expectations, this is only represented by two people.

6.2. Blockchain Benefits

All four participants provided an overwhelming case for the huge and potentially industry changing benefits of blockchain. We understand blockchain technology takes the form of a distributed ledger which by its nature of distribution creates transparency for the parties that trust in sharing data with the technology. The characteristic of transparency eliminates the opportunity for ethical misconduct which could entice organisations as suggested by Mason (2009).

We are living in a world where data is considered almost a commodity, such that the largest and fastest companies in the world such as Amazon, Facebook and Google can attribute their success to the data they control. As discussed during the interview, blockchain offers the ability to improve data integrity which in turn can optimise business processes for Small and medium enterprises also. Molbery (2020) discusses the ongoing challenges which companies face to prevent security breaches and threats to comprising data.

Although blockchain technology provides many benefits, it is ultimately only an infrastructure which relies on data input and trust in using the technology. The more organisations that trust and share using the technology, the more beneficial it will prove to be.

One of the participants identifies that blockchain technology has not successfully integrated into the industry despite all of the research and technology start-ups existing. He argues that although there are obvious benefits, that the technology needs to prove its worth in other industries first. Ge et al (2017) concludes in their report that blockchain is not a solution to all problems given its inability to store granular data.

Blockchain is a solution, but are there any better solutions on the market? There is no doubt it creates transparency, creates data integrity, and validates data to instil trust in the technology to replace trust in the entire industry.

6.3. Supply Chain Management

The research carried out during the literature review led the researcher to case studies involving the agricultural industry and blockchain technology and how they have successfully implemented the technology in improve the effectiveness of supply chain management and boost efficiencies also. (Bermeo-Almeida et al, 2018).

The Agricultural industry have migrated the technology with a supply chain platform which allows farmers to sell grain online. Sok (2019) found that the blockchain platform has proven to reduce waste, and improved efficiencies have led to higher profits for the buyers and sellers. Efficiencies from the software are driven by the automation of the software and the ability to rely on the integrity of the data alone and trusting that the security of the data has not been breached.

The principles applied to the Agricultural industry case study could be applied to the construction industry for the purpose of the sale of materials from suppliers and contractors to contractors and clients/developers. The research finds that the ownership and transfer thereof of equipment and plant on a project could be monitored as it moved from the manufacturer to supplier to contractor(s) to the facility owner. The real value add is the monitoring and sharing of the associated paperwork such as data performance sheets, warranties, etc. They can also be referenced securely through this digital process in an efficient manner which will improve the effectiveness of the facility maintenance plan after construction complete.

The significant volume of organisations involved on a project will generate an equally significant number of transactions between them. Some of these organisations may have existing relationships but the argument still stands whether existing relationships have a positive or negative relationship on ethical standards. Nonetheless, companies cannot rely on the integrity of data shared between them. Adnan et al (2012) conclude that misleading data can be in the forms of overstatement of capacity, experience, and qualifications. If adapted, blockchain technology could add huge value to the supply chain management by simply adding transparency and integrity to the data shared. Most participants agreed that supply chain management would be positively impacted by blockchain technology in some way.

6.4. Implementation

During the interviews, participants were aligned that the level and granularity of data was relevant when considering a strategy to implement it into a group. However, it was discussed by one participant that the more granular the data is, the probability of inefficiency increases. This is due to the time constraints to input the initial data with a limited or lesser output benefit. On the contrary, another participant argues that once a project has committed to digitalisation, the constraints of doing something at a granular level are no longer imposed. The likelihood of complete digitalisation on the majority of projects is low. This is due to the reason given by the first participant. As such, the level of granularity become very relevant to the effectiveness and efficiency of the implementation.

The research also suggests that the type of resources required to utilise blockchain technology will not differ to those already employed in the industry, albeit the process might change. The level of resource will reduce slightly as can be expected from the implementation of any successful technology. Blockchain requires data in order to be effective and considering the current state of the industry, it will require significant time and money to transition some aspects (projects and companies) of the industry into the digital space. This will require the time of data scientists, analysts, and subject matter experts to implement and consequently require investment and commitment from the organisations.

6.5. Industry Adaption

The adaption of the industry to new technologies proved an interesting discussion point with participant discussing their own personal experiences from both a success and failure perspective. This topic was initially researched during the literature review where the researcher found that Ellis (2020) and Lombardo (2020) made good arguments as to why the construction industry failed to adopt technologies over the past number of years. Ellis (2020) concludes that the obstacle for implementation sits with the lack of adequate resources in the industry suggesting that the professionals do not have the correct skillset and/or mind set. Lomardo (2020) concludes that technologies need more time to mature before the industry is ready to adopt them.

The participants in the research provide a range of new insights on this topic. It was discussed that adaption technology takes time and commitment. It cannot merely be

switched on and off and as such it needs commitment from the highest level. Company executives often have a timespan in control and if their decisions do not positively impact the performance of the company during their reign, it is not considered seriously.

Technologies such as Building Information Management have been adapted on some projects in the industry and to date it has been the most successful case of adaption in the industry, however this success can be put down to the fact that clients and contracts mandate this on their projects for their benefits as they enable digitalisation of designs and organisation of data.

An important note identified from almost all participants during the research was the importance of the value proposition for a successful adaption of technology. Technologies such as blockchain require everybody relevant to commit in order to ensure its success, and everybody will only commit if everyone can benefit from their commitment. If they can make their job easier and/or increase company profits then successful adaption seems guaranteed.

6.6. The Smart Relationship

It was identified during the literature review that neither blockchain nor smart contract technology relied on each other, however, research has identified the huge benefits they offer to each other. Consequently, the researcher has created this theme to discuss the findings of the relationship between them

Smart contracts are ultimately a digital twin of our traditional written contracts and contract administration form a very important and sensitive part of every construction project. Risk surrounding data security, data breaches, data integrity have resulted in huge hesitancy in the industry to adapt to smart contract technology and thus choosing to retain the status quo.

Blockchain technology on the other hand requires a number of characteristics to boost its potential success. It needs data and it needs commitment from parties to trust and utilise the technology. In summary Smart contracts need a validation tool and blockchain needs data and commitment. Thus, the 'smart relationship' evolved. Research finds that smart contracts could be a viable solution to implement blockchain and test its effectiveness.

7. Conclusion

7.1. Limitations of this Study

This study was in the midst of a pandemic which has thrown the whole world into a digital era and enhanced how we view technology. Therefore, this research could be strongly influenced by technological perceptions that currently exist. Whether the reliance and adoption of digital process will continue to grow is unknown and it could be argued that as we exit the pandemic crisis, which has transformed our perception of technologies, it could also allow us to become less reliant on same.

This paper was carried out with time constraints which prevented the researcher from investigating further research questions derived from the study completed.

Only five participants were interviewed as part of this study. On reflection, the researcher would have preferred a wider pool of findings but given the limited knowledge of the research topic in the industry, there were limitations on the number of potentially available participants.

7.2. Conclusion

It is clear from the literature and research that blockchain technology has the characteristics to secure data and create transparency, thus replacing trust. The technology has already started to have success in the agricultural industry. The researcher concludes that blockchain could replace the role of trust in the construction industry, however the following caveats do apply. The technology has limitations and should be applied in a suitable environment in order to be effective. As discussed previously, it relies on digital data to be utilised and shared and therefore the second caveat is engagement. In order to fully benefit from the technology, all stakeholders must fully trust in and engage with the technology. It cannot be fully effective as a means for data validation if the technology is not fully engaged. Finally, it must be noted, that blockchain technology may not be suitable for all types or sizes of projects. As discussed during the research, the technology may not prove effective if deployed on a project too small.

The research carried out surrounding Smart contracts proved worthwhile and a conclusion is drawn that smart contract technology is a viable solution to partner with and utilise blockchain technology for medium and large-scale projects.

Another aim of the research was to understand the limitations of companies adapting innovative solutions in the industry. Some really interesting findings were noted, and it is the opinion of the researcher following their extensive research that the key to successfully introducing an innovative technology to the market is to ensure the technology offers a value proposition for all stakeholder which engagement is required from. It is found that mandating technology is also a solution but will not prove as effective.

It is also concluded following the conclusions of Mason (2009) and others, that ethical misconduct is a risk in the construction industry. Mason (2009) concludes that ethical misconduct can only be prevented by reducing the numbers of situations where contracted parties consider it necessary to seek an advantage at another's expense. Blockchain technology offers a clear and definite solution to this.

The researcher concludes that Blockchain technology can replace the role of trust in the construction industry provided it is offered and implemented into the industry strategically with consideration for project type and size as discussed previously.

7.3. Recommendations

This report makes the following recommendation for further research:

Following the conclusion above, further research into specifically how and where blockchain can be applied to the construction industry in order to be most effective. This research may be more beneficial if carried out using a quantitative method in order to consider a larger group of participants and not just those with a digital background and experience. The findings made during the interviews in relation to the lack of impact blockchain technology has had to date provides concern.

On a similar note, the research surrounding the perception of ethical standards and ethical misconduct should be explored further. Further research could offer more detailed findings and in turn provide a better solution to improve effectiveness.

Finally, it was concluded that Blockchain can replace the role of trust, but it cannot be confirmed if it is the only solution or the best solution. Further research should be carried out to research and better understand the competitive technologies after which an in-depth SWOT analysis should be carried out.

8. Appendices

Appendix 1 – Interview Questions

1.   How did you first get introduced to blockchain technology and what has been your experience to date?

2.   A blockchain is essentially a digital ledger of transactions that is duplicated and distributed across the entire network of computer systems on the blockchain. What are the main benefits of blockchain in your opinion?

3.   Blockchain is commonly associated with crypto currencies and has been a key driver to their success and popularity over the past years. Can the benefits of blockchain such as record-keeping, transparency and verification be used effectively for materials and equipment (not currency/finance)?

4.   Do you think blockchain could improve supply chain mechanisms by alleviating such things as trade tariffs trading documentation etc.

5.   What resources and software would be required to implementation such process and how could it be implemented effectively?

6.   What are biggest challenges that have been faced to date implementing blockchain into the construction industry?

7.   How can we overcome these challenges moving forward?

8.   The construction industry has traditionally failed to innovate and adapt to new technologies and innovative processes. Do you feel this can be overcome? How?

9.   It is the opinion of some, that ethical standards in some construction markets are not satisfactory. Could blockchain technology be used as a solution to improve this perception? How?

10.   Have you any experience of how blockchain could assist with implementation of iContracts and verification and automation of contract clauses and processes?

9. References

Adnan, H., Hashim, N., Mohd, N., Yusuwan and Ahmad, N., 2012. Ethical Issues in the Construction Industry: Contractor's Perspective. Procedia - Social and Behavioral Sciences, 35, pp.719-727.

Benarroche, A., 2020. How Does A Guaranteed Maximum Price (GMP) Contract Work?. [online] Levelset. Available at: <https://www.levelset.com/blog/guaranteed-maximum-price-gmp-contract/> [Accessed 11 January 2021].

Bermeo-Almeida, O., Cardenas-Rodriguez, M., Samaniego-Cobo, T. and Ferruzola-Gómez, E., 2018. Blockchain in Agriculture: A Systematic Literature Review.

Black, C., Akintoye, A. and Fitzgerald, E., 1999. An analysis of success factors and benefits of partnering in construction. International Journal of Project Management, 18(6), pp.423-434.

Braun, V. and Clarke, V., 2008. Qualitative Research in Psychology. University of Auckland.

Brown, R., 2021. Five Years Of Enterprise Blockchain: What Have We Learned? And Where Next?. [online] Forbes. Available at: <https://www.forbes.com/sites/richardgendalbrown/2020/10/16/five-years-of-enterprise-blockchain-what-have-we-learned-and-where-next/?sh=49129dc523e6> [Accessed 19 June 2021].

Chan, D., Chan, A., Lam, P., Yeung, J. and Chan, J., 2011. Risk ranking and analysis in target cost contracts: Empirical evidence from the construction industry.

Cidik, M., 2021. Construction productivity and digitalisation: An I.T. productivity paradox perspective. 5th Annual ARCOM,.

Clark, L., 2016. The Principles Of Open-Book Pricing. [online] Info.waterdesignbuild.com. Available at: <http://info.waterdesignbuild.com/blog/the-principles-of-open-book-pricing> [Accessed 24 December 2020].

Project Ireland 2040, 2019. Construction Sector Performance and Prospects 2019.

CRAIG, D., 2021. Why Building Trust is Essential for Success. Jobsite,.

Cullen, P., 2019. What lies behind the children's hospital's ballooning budget?. Irish Times,.

EKA, .., 2021. How Does Blockchain Help the Agriculture Industry?. Global Trade Mag, March 11th 2021.

Ellis, G., 2020. Blockchain In Construction: 4 Ways It Could Revolutionize The Industry - Digital Builder. [online] Digital Builder. Available at: <https://constructionblog.autodesk.com/blockchain-in-construction/> [Accessed 6 January 2021].

Essex, D., 2021. Blockchain for Businesses: The Ultimate Enterprise Guide. [online] SearchCIO. Available at: <https://searchcio.techtarget.com/Blockchain-for-businesses-The-ultimate-enterprise-guide> [Accessed 15 June 2021].

Gandhi, S., Eceiza, N., Teh, Y., Li, D. and Xu, R., 2021. Exploring the value of enterprise blockchain.

Ge, L., Brewster, C., Spek, J., Smeenk, A. and Top, J., 2017. Blockchain for Agriculture and Food. Wageningen Economic Research, December 2017.

Hertig, A., 2021. What Is an Enterprise Blockchain? - CoinDesk. CoinDesk.

Kennedy, L. and Montgomery, A., 2018. Exploring Qualitative Research. Centre for Effective Services,.

Levy, F., Thompson, G. and Wiest, J., 1963. The ABCs of the Critical Path Method. Harvard Business Review, September 1963.

Logan, B., 2020. Ethnography: When and How to Use It | Spotless. [online] Available at: <https://www.spotless.co.uk/insights/ethnography-when-and-how/> [Accessed 30 July 2021].

Lombardo, J., 2020. Three Keys to Technology Adoption in the Construction Industry.

Manukyan, N. and Papadonikolaki, E., 2019. Digitalisation in construction: Mixed blessing for collaboration in projects. Project Management (PM) Congress: Research meets practice 2019,.

Mason, J., 2009. Ethics in the construction industry: the prospects for a single professional code. International Journal of Law in the Built Environment, 1(3), pp.194-204.

McNamara, A., 2019. Automating the Chaos:Intelligent Construction Contracts. Built Environment Economist, December 2019.

McNamara, A., 2020. Automating the Chaos: Intelligent Construction Contracts. Smart Cities and Construction Technologies,.

McNamara, A. and Sepasgozar, S., 2020. Intelligent contract adoption in the construction industry: Concept development. Automation in Construction, 122, p.103452.

Mølbjerg, R., 2021. Enterprise Blockchain | Deloitte. [online] Deloitte Danmark. Available at: <https://www2.deloitte.com/dk/da/pages/technology/nextgen-blockchain.html> [Accessed 2 May 2021].

Rogers, E., 1983. DIFFUSION OF INNOVATIONS. 3rd ed. New York: Macmillan Publishing Co., Inc, pp.246-250.

Shah, R. and Alotaibi, M., 2018. A Study of Unethical Practices in the Construction Industry and Potential Preventive Measures. Journal of Advanced College of Engineering and Management, 3, p.55.

Sok, H., 2019. Blockchain Changes the Pace for Agricultural Supply Chain. Global trade Mag, January 20th, 2019.

Tan, Y., Xue, B. and Cheung, Y., 2017. Relationships between Main Contractors and Subcontractors and Their Impacts on Main Contractor Competitiveness: An Empirical Study in Hong Kong. Journal of Construction Engineering and Management, 143(7), p.05017007.

Viator, M., 2020. What Does "Pay When Paid" Mean In A Construction Contract?. [online] Levelset. Available at: <https://www.levelset.com/blog/what-does-pay-when-paid-mean/> [Accessed 30 November 2020].