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Final Year -Thesis

Is the first step to implementing Intelligent Contracts in the Construction Industry through BIM integration?

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Declaration

This study was completed for the MSc in International Construction Law at the University of the West of England, Bristol. The work is my own. Where the work of others is used or drawn on it is attributed.

Signed……..

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Abstract

The construction industry has a reputation for being adversarial and motivating dispute. There is evidence to suggest that 50% of all legal costs associated with construction projects are a direct result of dispute (Chern, 2010). Improvement in the Industry has been sought through collaborative practices since the (Latham, 1994) and (Egan, 1998) reports stipulated the deficiencies of the industry. Many innovations have been implemented, and while there have been some breakthroughs, progress has been slow.

The adage that '*Contract is King'* runs deep in the industry and the incremental steps taken by the new wave of multi-party and partnering contracts have paved the way for what perhaps could be the disruptive change required to finally force collaboration into the industry. The Intelligent Contract tool could replace current construction contracts and supply efficiency and value that can force the industry into collaboration out of necessity rather than appeal.

The incorporation of BIM into the process could see the concept contractually bridging the gap between all phases of the development cycle. Building Information Modelling (BIM)'s establishment in the industry could offer a platform on which Intelligent Contracts can be based upon.

Greater administrative efficiency would reduce costs and lead to less minor disputes. Surety of payment would lead to more small companies being able to operate with confidence in the sector. Transparency of contract terms would drive collaboration and make the industry more attractive to all stakeholders' due to the greater definition of risk within any project. The input required to make the concept a success in the Sector is colossal. Creating an environment where the sophistication of data exists from all stakeholders, that will be the fuel for a central Intelligent Contract system, will require a huge step towards the digitisation of the industry.

"I suppose it is tempting, if the only tool you have is a hammer, to treat everything as if it were a nail." – Abraham Maslow (1966)

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Chapter 1 – Introduction

SCOPE OF THE CHAPTER

This chapter gives an overview of the thesis. It sets out: the research question; aims and objectives; and a summary of the research methodology.

RESEARCH QUESTION

The research will focus on how Intelligent Contracts could be best implemented within the construction industry and how BIM could offer the initial catalyst for their adoption. Has the industry's adversarial history led to a point where a truly innovative and disruptive change is required at the very heart of the binding contract in the construction project? Is the need to force parties to trust, rather than appeal to them to do so, what is required after the slow acceptance of collaborative culture?

The primary aim of this research is to answer the research question:

Does BIM offer a definitive platform for the implementation of Intelligent Contracts in the construction industry?

OBJECTIVES

To answer this question, the following objectives have been established:

1. Identify the progress made in collaborative contractual and management methods in recent decades including a review of the progress made with BIM.
2. Investigate the acceptance of BIM and the Industry's outlook on the adoption of Intelligent Contracts in the future.
3. Understand the key aspects of Intelligent Contracts and other technologies and factors that would partner the Intelligent Contract concept.
4. Evaluate whether an opportunity exists for the adoption of Intelligent Contracts through integration with current and future BIM practices.

RATIONALE

The construction industry has a reputation for being adversarial and motivating dispute. In Australia, there is evidence to suggest that 50% of all legal costs associated with construction projects are a direct result of dispute (Chern, 2010). According to the ARCADIS Global Construction Disputes Report 2016, the global dispute value is down from US$51 MILLION in 2014 to US$46 MILLION in 2015 but the average length of these disputes has increased from 13.2 months to 15.5 months in the same period. The continuing trend observed over the past 6 years is that disputes are increasing in both value and in the length of time taken to resolve them (ARCADIS, 2016).

The ARCADIS report shows the ranking of the main causes for dispute in 2015 globally:

1. Failure to properly administer contracts;
2. Poorly drafted or incomplete and unsubstantiated claims;
3. Errors and/or omissions in the contract document

Main Contractors can be especially susceptible to disputes due to the complexity of overseeing a construction project and the risks involved (Klee, 2015). Add into this the difficulty of an international construction project, where stakeholders and vendors may span the globe with different jurisdictions and laws, and you have a machine with a lot of moving parts that may not fit perfectly together. Understanding how to adequately deal with any dispute that arises in a project is often the difference between success and failure (Lamont, 2016).

Ultimately, when any dispute arises the best outcome is for the relevant parties to attempt to resolve it directly. Many contracts will give guidance that this is the first action to be taken when any dispute occurs. However, there may come a time when this primary process breaks down and alternative means of dispute resolution must be sought by bringing in a third party to facilitate a number options. The onerous nature of human administration in any construction contract dispute is something that could be potentially alleviated through automation of the process, even if only partially.

ARE CONSTRUCTION CONTRACTS THE SOURCE OF THE PROBLEM?

At the centre of all construction projects is the contract between the client and contractor and, as any construction project is a relatively complex process, the industry has demanded contracts of greater sophistication as the sector has evolved. The recommended use of one single standard form of contract for the construction sector has existed since the (Banwell, 1964) report, and since then there has been a range of organisations producing their own suite of contracts competing for use within the industry.

There are some difficulties brought upon by the vast choice of standard construction forms including the dissatisfaction of the current crop. The need to heavily amend construction contracts to suit individual construction projects still exist and require the careful consideration of project specific parameters to be inserted in order to achieve a successfully executed contract for all stakeholders (Foreward, 2002). Stakeholders in the industry grapple with numerous forms of contracts that are available in the industry. Data from 2012 shows that the JCT suite of contract has a 48% use in the UK market with NEC recording 22% and FIDIC at 4% (Mason, 2016).

According to (Loosemore & Hughes, 1998), traditional construction contracts are inflexible, restrictive and ineffective and project participants tend to opt out of contract procedures that are prone to change which lead to a loss of organizational and managerial control. The perception that contractual relationships are mainly based on confrontational situations that reflect the level of trust (or lack thereof) in the contract documents is predominant in the construction sector. The trust relationship between the contracting parties provides some opportunities for developing a better risk allocation mechanism and contracting strategies, as well as significant saving for construction (Zaghloul & Hartman, 2003).

Abrahamson's seminal paper discussing risk management within the construction industry raised the fundamental issue that risk on a construction project should be allocated to the party best placed to carry the risk. That is to say, it should be allocated to the party that is best able to:

- Control the risk, or;

- Insure the risk, or;
- Manage the risk, or;
- Sustain the consequence.

The evaluation of what party will be more negatively or positively affected if the risk does or does not take place must also be a consideration when balancing any contract based on the intention of the contracted parties. There is long list of biased amendments that can be imposed upon unwary contractors. The formation of a concise strategy to assess the risks from any contract and respond appropriately so as to mitigate exposure is a must to the successful operation by any contractor or sub-contractor. (Mason, 2016)

In the United Kingdom, standard form contract providers stand at a cross-roads on whether multi-party contracts, encouraged by the partnering ethos, is the way forward (Saxon, 2016). The industry outlook in the last decade has centred on partnering arrangements which are still very reliant on the duty of good faith between the contracting parties (Mason, 2007). The deep cultural adoption of a distrustful approach to contracts and the adversarial nature of the industry has seen partnering and framework agreements falter within the industry (Mason, 2017). Could the very crux of the industry's problems in executing contracts be human nature? It is said that the term "business ethics" has been deemed an oxymoron in the industry (Mason, 2009).

A traditional construction project's procurement may follow the following simplified process.

- Client employs consultants to create tender documents
- Tenders are called and a main contractor engaged
- The main contractor then engages multiple sub-contractors to carry out specialist works on site
- A construction contract is entered into, administered and monitored by the client's project management representative.
- To handover a building requires various sign offs, certifications and warranties are in place between the multiple stakeholders.

Figure 1 shows the multi-contractual links over the main stages of a construction project and as you can see, due to the multiple stakeholders involved in a construction project,

the contract administration required and the time needed for each stage of the process is extremely onerous. The full or semi-automation of contract administration alone which could be achieved through implementing Intelligent Contracts would stand to save the industry an attractive percentage of any projects costs (Cardeira, 2015).

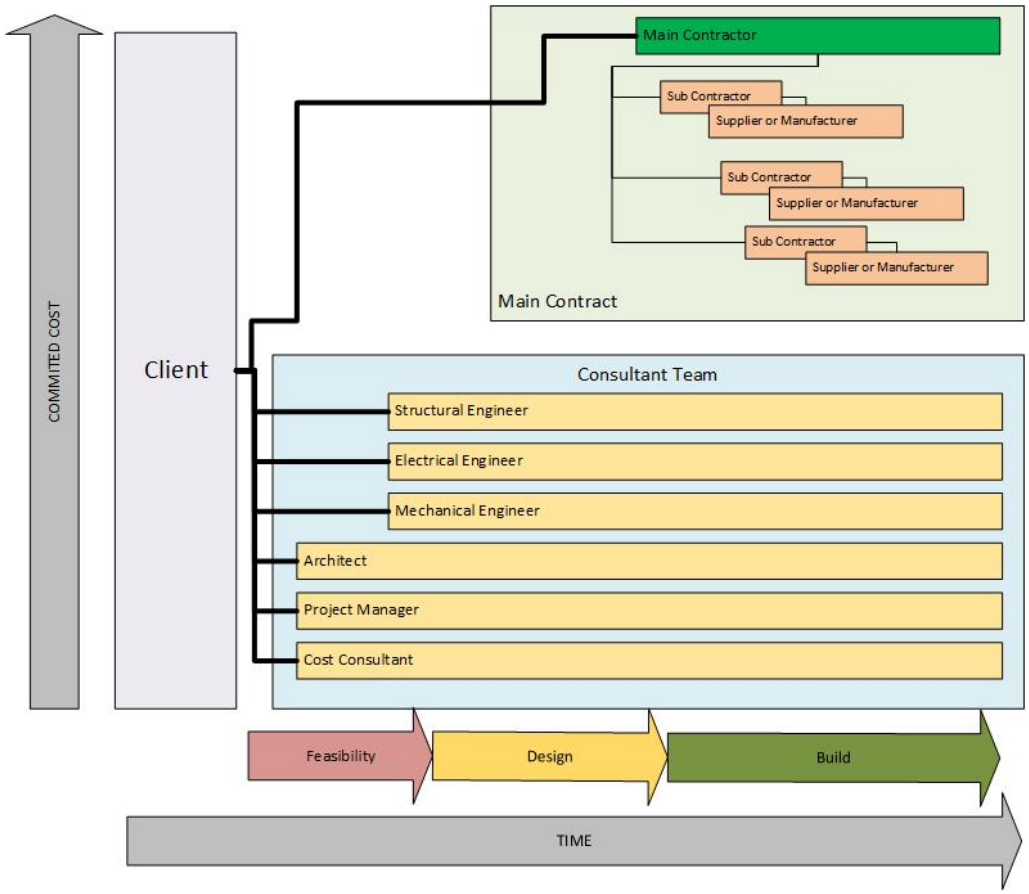

Figure 1: Tradition Contract Relationships (Hughes, 2017)

INTELLIGENT CONTRACTS AND BIM

Simplistically, smart contracts are computer protocols that facilitate, verify, or enforce the negotiation or performance of a contract, or that obviate the need for a contractual clause (Szabo, 1994). The proposal of embedding the terms and conditions of an agreement into a physical item contrasts immensely from a traditional paper contract

which, upon being agreed, is used only as a reference when the parties are in dispute. Smart contracts allow for a set of instructions to be incorporated into a contract allowing clauses in smart contracts to be self-executing, self-enforcing, or both (Cardeira, 2015). Smart contracts in the United Kingdom denotes a process where the user author selects the appropriate terms with the help of a computer program. Intelligent Contract is the term used when a contracts purpose is to manage itself (Mason, 2017). The Intelligent Contract will set out the requirements and decision inputs (hold points) in order to start a series of **if / then's** that will execute the terms of the contract between client and different members of the project team, main contractor, sub-contractor to design, monitor, approve, tender, install, certify and take handover of the built asset (Hughes, 2017). The incorporation of BIM into the process could easily see the concept contractually bridging the gap between the construction phase through to the facilities management of the asset.

Building Information Modelling (BIM)'s establishment in the industry could offer a platform on which Intelligent Contracts can be based upon. BIM offers a centralised database of all project information which an Intelligent Contract can draw upon for all necessary information to execute the terms of the contract. The translation issues of BIM acronyms and terms into existing traditional contracts highlighted by (Mosey, et al., 2016) would be avoided through the full integration of a BIM model with the Intelligent Contract. Other issues that have faced the industry's acceptance of BIM, such as intellectual property licences over user's contribution to a project BIM, would be made clearer through the more logical progression of a 'black and white' Intelligent Contract. The 'black and white' or '1 or 0' execution of an Intelligent Contract is in itself a huge obstacle to overcome in adopting the potential technology in the construction industry. This is due to the complexities of the construction process requiring judgement and discretion which would normally be handled through subtlety and refinement in the language of traditional contracts (Mason, 2017). The language of code does not allow for grey areas, but could this be the catalyst for changing the combative attitude of the industry by forcing parties to agree most, if not all, terms prior to engagement?

PROBLEM FORMULATION & HYPOTHESIS

It can be concluded that improvement in the Industry has been sought through collaborative practices since the (Latham, 1994) and (Egan, 1998) reports stipulated the deficiencies of the industry and the need to shift from the historically adversarial attitudes that has plagued the sector. Many innovations have been implemented, and while there have been some breakthroughs, progress has been slow. The fanfare of BIM technology brought with it all the pomp and promise of a technology saviour that would transform the industry. Unfortunately, the old-school construction attitude has prevailed to date and acceptance in the industry has been limited, although some traction has been achieved through some government initiatives.

The adage that '*Contract is King'* runs deep in the industry and the incremental steps taken by the new wave of multi-party and partnering contracts have paved the way for what perhaps could be the disruptive change required to finally force collaboration into the industry through necessity rather than appeal. By replacing the 'hammer' that is the current construction contract with a more streamlined, efficient and collaborative tool that Intelligent Contracts could be, perhaps the industry will stop treating each other as a nail to be hammered?

Hypothesis 1:

By creating an all-encompassing contract process - that: ensures all parties adhere to the terms agreed; which offers protection of payment, insurance and data; as well as the potential to increase efficiency and reduce risk - it should make the successful implementation of Intelligent Contracts the top priority for the Construction Industry.

The first step to making this possible would be to build on the momentum that the BIM agenda has created and to compliment the BIM platform before evolving into further technologies.

Hypothesis 2:

The industry is nowhere near mature enough to facilitate such a disruptive technology that would essentially change the way construction projects are run. Attitudes to streamline the procurement and contract process are that projects are far too complex to

simplify into what would essentially be a manufacturing model and the appetite to change does not exist across enough of the industry to succeed.

Hypothesis 3:

The level of BIM usage and the capabilities of the major platforms are not at a stage yet where the platform could be harnessed to facilitate the implementation of Intelligent Contracts. Potential user numbers would not be viable and technology capabilities are not sophisticated enough.

THESIS PLAN & METHODOLOGY

This Thesis is composed of the following Chapters:

Chapter	Heading
1	Introduction
2	Analytical Literature Review of BIM and Collaborative Practice
3	Analytical Literature Review of Smart Contracts & Beyond
4	Research Design and Methodology
5	Results and Discussion
6	Interpretation of Findings and Conclusions

Table 1: Table of Chapters

Chapter	Description
2	A literature review of BIM and other collaborative practices within the industry. It introduces the concepts of BIM and how it has evolved over the years, along with commentary on acceptance within the industry. The drivers and barriers to BIM and collaboration within the sector shall be explored and summarised.
3	A literature review of Smart Contracts summarising the history of the technology along with the underlying principles and processes. The evolution of blockchain, cryptocurrencies will also be touched on in summarising the evolution of the topic. Adaption and barriers to implementing with BIM will also be commented on.
4	Explains the methods and approach taken in the research methodology and the gathering of empirical data as part of the study across industry professionals.
5	Presents the results of the empirical research. Commentary on the data will be given with summaries given. More measured commentary will validate the findings against itself (other subjects) and the quantitative data from previous chapters.
6	Summarises the major findings and contribution of the research with regard to the initial hypothesis proposed while also reflecting on the limitations of the research. Conclusions and recommendations for further research will be proposed.

Table 2: Summary of Chapter Content

RESEARCH METHODOLOGY

The following strategy will be followed in order to achieve the aims and objectives of the research.

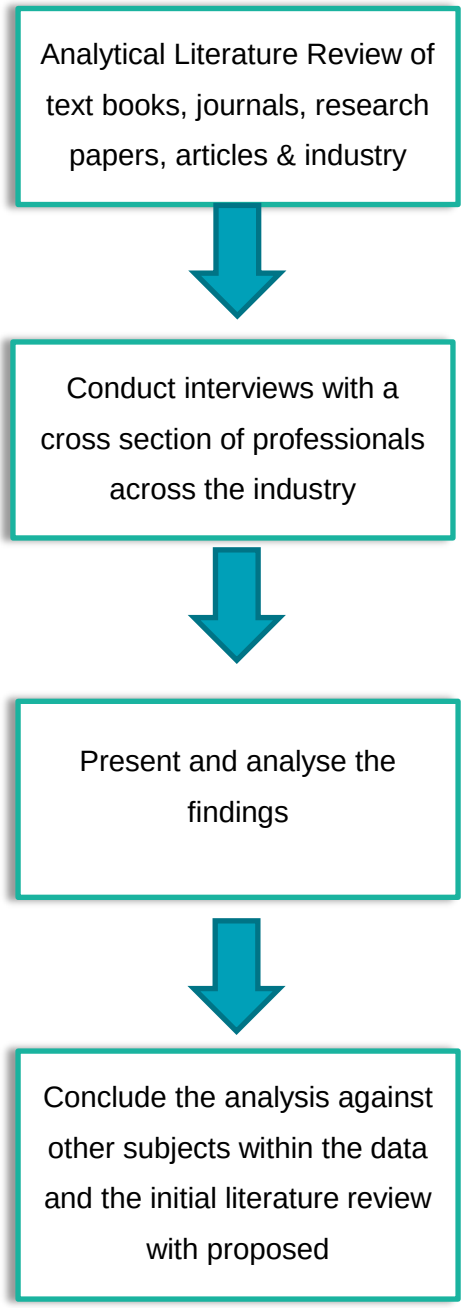

Figure 2: Research Stages

Chapter 2 - Analytical Literature Review of BIM and Collaborative Practice

SCOPE OF THE CHAPTER

This chapter will explore the concept of collaboration within the construction industry along with the history and evolution of BIM through an investigation on the available literature. The drivers and barriers to BIM and collaboration within the sector shall be explored and summarised.

HISTORY AND EVOLUTION OF COLLABORATION AND PARTNERING WITHIN THE INDUSTRY

The construction industry is often sighted as lagging behind other industrial sectors in all facets from cultural evolution and project efficiency through to profitability and customer satisfaction (Barrett, 1998). There have been many reports and articles written on various incremental and disruptive innovations that have built on the influential (Latham, 1994) and (Egan, 1998) reports. These instrumental reports championed that increasing collaboration would overcome the fragmented and adversarial nature prevalent within the industry (McNamara, 2002).

(Latham, 1994) first promoted the premise of partnering as a means for ridding the industry of its adversarial nature. (Egan, 1998) built on this foundation and proposed the notion of long term partnering/ framework agreements during procurement which would be, "…based on clear measurement of performance and sustained improvements in quality and efficiency."

In the (Constructing Excellence, 2011) guide, six key critical success factors were identified including the need to integrate collaboration into education and culture (Dale, 2016). The three over riding principles of 'Common vision and leadership'; creating a 'Collaborative culture and behaviour' and; implementing 'Collaborative processes and tools' were highlighted. BS11000, in the same year, looked beyond the construction industry and provided a framework for collaborative business relationships, to help companies develop and manage their interactions with other organisations.

While *Construction 2025* (HM Government, 2013) does not set collaboration as a specific goal, a SWOT (strengths, weaknesses, opportunities, and threats) analysis within the report classes collaboration as: a weakness - due to limited knowledge-sharing from projects which are often team-based with knowledge lost when the team breaks up at project completion; an opportunity - through BIM which it states could improve sector productivity and lower costs due to improved information flow and greater collaboration; and a threat - due to fragmentation in the sector which impacts on levels of collaboration, innovation and ability to access foreign markets.

The Government Construction Strategy (GCS) 2016-20 set out the Government's plan to develop its capability as a construction client and act as an exemplary client across the industry. It built on the success of GCS 2011-15 and including the development of collaborative procurement practices, developing a collaborative culture within the supply chain and mandating BIM on all centrally procured projects moving towards BIM level 3 maturity. (The Infrastructure and Projects Authority, 2016)

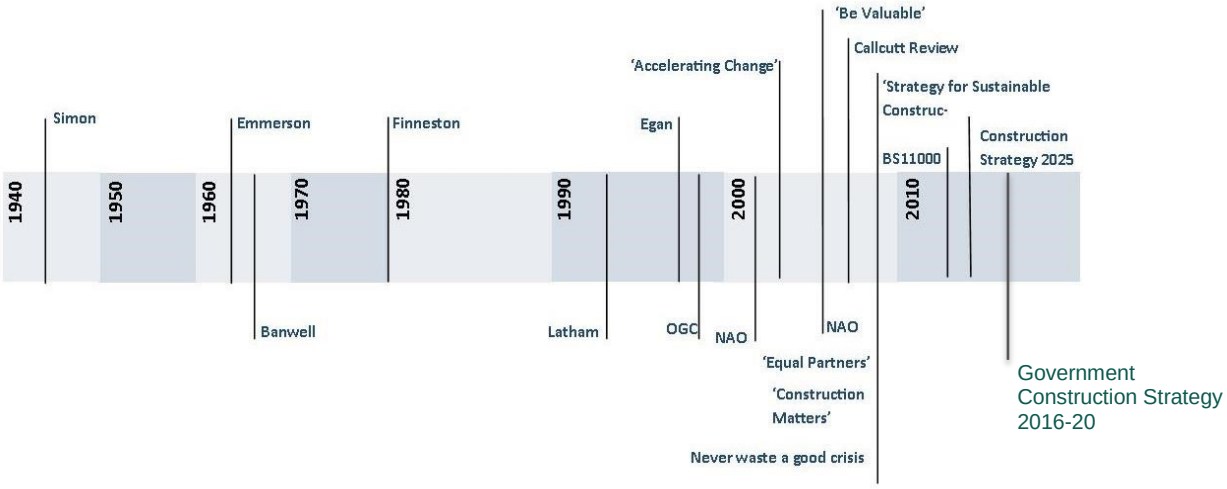

Figure 3: Timeline of Key Industry Reports on Collaboration - adapted from (Constructing Excellence, 2009)

Seeking to address the issues raised in the numerous reports on construction sector practices, the industry has responded with many tools and process that have provided

guidance on the best practice of implementing collaboration. However, the successful implementation of collaborative technologies is reliant on the environment being collaborative. This has at times created a 'cart before the horse' scenario as many of these technologies have been produced in order to create such an environment (Briggs, 2006). (Kvan, 2000) claims collaborative environments cannot be created using software tools and that collaborative technologies are more successful when collaborative working environment already exists prior to implementation.

HISTORY AND EVOLUTION OF BIM WITHIN THE INDUSTRY

The concept of BIM is not attributed to one person or organisation but is an evolution of innovative technologies stretching back to the early days of Computer Aided Manufacturing and Design in the late 1950s and early 1960s.

In 1975 Charles Eastman published a paper describing what he called a Building Description System (BDS). The paper discussed the ideas of parametric design, high quality computable 3D representations, with a single integrated database for visual and quantitative analyses. Eastman's paper was extremely forward thinking and essentially describes BIM as we now know it (Goubau, 2017). The BDS was one of the first projects in BIM history to successfully create this building database; it described individual library elements which could be retrieved and added to a model. Eastman concluded that BDS would improve drafting and analysis efficiencies while cutting the cost of design by more than fifty percent (Eastman, 1975). BDS was to be the experiment that identified the most fundamental problems in architectural design which played out over the next five decades (Goubau, 2017).

Robert Aish first documented the use of the term "Building Modelling" in a paper in 1986. A few years after that, the first documented use of the term "Building Information Model" appeared in a paper by G.A. Van Nederveen and F. Tolman (Goubau, 2017).

As the technology began to gain traction the key industry players followed different strategies. Some relied on their traditional main CAD platforms and built BIM solutions around them (Bentley Systems, Nemetschek AG), while others developed entirely new modelling engines (Autodesk). In all cases, a complex blend of CAD and Architectural,

Engineering and Construction industry (AEC) technologies established the foundation of 3d parametric modelling.

Parametric modelling allowed the industry to change drawings at multiple scales and across fragmented drawing sheets saving hours from achieving the task manually. The employment of computer technology automated long-winded tasks in all disciplines, thereby greatly improving productivity across the AEC industry (Goubau, 2017).

During the same period, CAD, and AEC, became universally parametric. AEC and IM were integrated to become BIM as we now know it. This aggressive software development activity coincided with exponential economic growth in the construction sector. (Wierzbicki, et al., 2011).

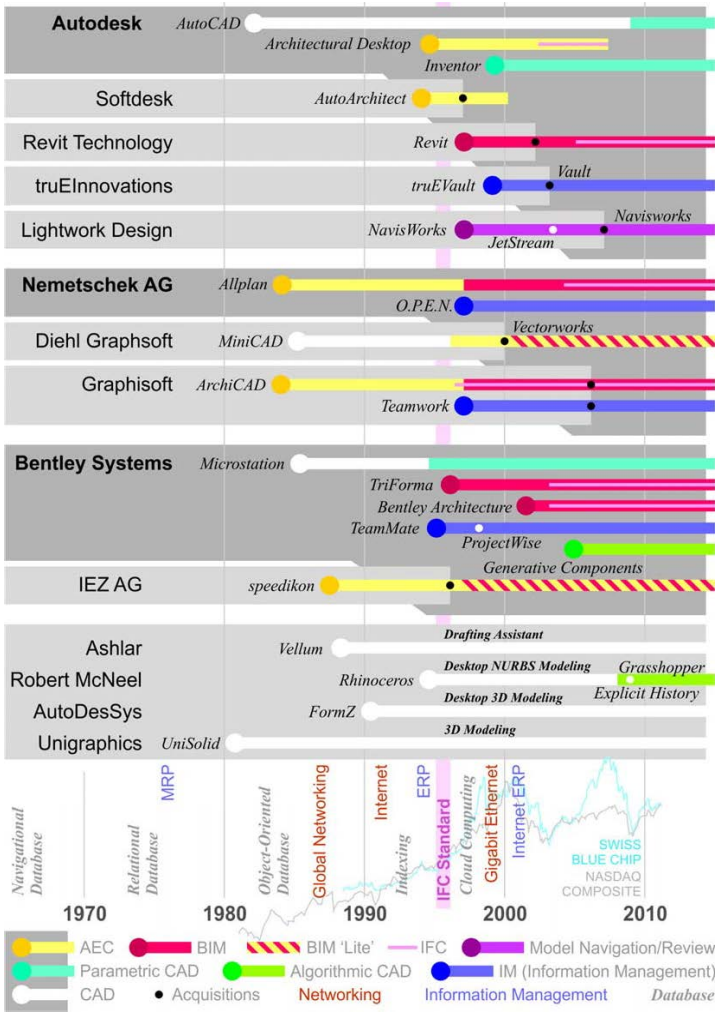

Figure 4: BIM Technology and chronology. (Wierzbicki 2011)

BIM AND COLLABORATION – CURRENT STATUS AND FUTURE

Many commentators in the UK adopt the definition of BIM coined by Keith Snook, former RIBA director of research, “Building Information Modelling is a digital representation of the physical and functional characteristics of a facility creating a shared knowledge resource for information about it forming a reliable basis for decisions during its life cycle, from earliest conception to demolition.” BIM requires all players in a construction project to work collaboratively and share information in a way that has not historically been done in the industry (Brook, 2014).

The Government Construction Strategy (GCS) 2011-15 mandated the industry to use BIM level 2 on Government projects and must demonstrate collaborative practices in order to win Government contracts as BIM is a tool that encourages,” … open, collaborative working.” (HM Government, 2015)

BIM increases the scope and speed of data exchange which highlights the input required, the timing of the input and the reliance of the data from any member of a project team. The proposition is that this process enables and depends upon increasing collaboration as a means for success (Mosey, et al., 2016). For BIM to be truly used to its full potential, a collaborative environment must be present to offer ‘real-time’ collaboration. The 2015 NBS National Survey noted that 57% of those surveyed agreed with this and most described their contract form as collaborative, especially users of the NEC3 or PPC2000 form of contract (Mosey, et al., 2016).

Some standard form contracts have adopted a light touch in relation to the inclusion of BIM provisions with many using clauses that simply refer to the Construction Industry Council (CIC) BIM Protocol. The CIC Protocol is designed to encourage BIM adoption through a series of supplemental contract documents which are signed by the client and then bi-laterally with the main contractor, subcontractors and consultant that make up the project team. This network of bi-lateral contracts is the alternative to a multi-party contract and serves the purpose of creating the necessary ‘consensus ad idem’ well in its absence (Mason, 2017).

The flawed nature of the industry’s attitude is evident in the CIC Protocol (Mason, 2016). The lack of warranty in relation to the integrity of electronic data transfer, before and

after transmission, and the lack of liability for the modification, amendment, transmission, copying or use of BIM models other than for the agreed purpose. The most obvious limitation of the CIC Protocol however is in clause 4.1.2 where the production of models in accordance with the Agreed Levels of Detail specified in the Model Production and Delivery Table to 'reasonable endeavours'. As (Mosey, et al., 2016) states, "*this is a lower, less clear duty of care than the widely accepted standard of reasonable skill and care."* This is of course unclear, and has been interpreted by the courts in many ways according to the context in which it is used (Mosey, et al., 2016).

A growing interest in the role that multi-party contracts play in successfully supporting BIM enabled projects has been evident in the use of PPC2000 and other comparable multi-party contracts that have been developed in Australia and the USA (Mosey, et al., 2016). The cooperative nature of these contracts creates the necessary environment for BIM to be optimised. When we contemplate the implementation of BIM level 3 the level of collaboration is starting to rely more on stigmergic collaboration where each piece of work is indistinguishable from the next and the author is not notified of any changes to their contribution by other project members (Elliot, 2006). Collaboration at this level is most certainly reliant on a multi-party contract, if only to deal with the liability of the project insurance (Mason, 2016).

BARRIERS

"The overriding message…points to clear collaboration if BIM is to be a success. Collaboration is not, however, a new concept for the industry. For over a generation, the government and industry stakeholders have strived to create a utopia of a more collaborative construction industry with, albeit limited, success." (Pinset Mason, 2014)

The success of implementing any new technology depends on many factors. For example, personnel's attitudes toward new technologies are shaped by the risks involved in using unknown means and methods, the difficulty of implementation, financial risks, and the perception of other workers' attitudes toward new technologies (Tatum, 1989). While BIM is expected to deliver many benefits to the industry, a range of barriers have hampered its widespread implementation. (Liu, et al., 2015) categorised these into

five major groups: lack of a national standard; the high cost of application; the lack of skilled personnel; organisational issues; and legal issues. Each barrier can then be divided into two or three sub-groups, as shown in Table 3. Each barrier to BIM implementation has influence over others as shown in Figure 4 which shows the links between BIM implementation and the five categories of barriers (Liu, et al., 2015).

Category	Sub Category/Item
Lack of a national standard	Incomplete National Standard Lack of information sharing in BIM
High cost of application	High initial cost of software High cost of implementation process
Lack of skilled personnel	Lack of BIM professionals High cost of training and education
Organisational issues	Process problems Learning curve Lack of senior support
Legal issues	Ownership Responsibilities for inaccuracies Licensing problems

Table 3: Summary of Barriers in BIM implementation (adapted from (Liu, et al., 2015))

Standards are common throughout the every facet of the AEC industry but successful BIM implementation requires the development of new standards pertinent to the technology (Liu, et al., 2015). The lack of appropriate governing standards for sharing data between all stakeholders in the development process is seen as a barrier to the technology being accepted (Allen Consulting Group, 2010).

Data inconsistency is the most prominent data-related barrier as well as data compatibility between stakeholders. Willingness to share information among project stakeholders is critical to BIM, therefore any issue with transmitting and reusing the BIM data constitutes a very real barrier to BIM implementation (Aibinu & Venkatesh, 2014). A survey taken by the National Building Specification (NBS) organisation showed that a single BIM data platform is yet to be established and 26% of BIM users relied on multiple pieces of software (Mason, 2017). The interoperability of BIM software is seen as an issue but it is one that is being addressed, by new tech company flux.io, in the next wave

of AEC technology. Flux.io are investigated further in this paper regarding their solution for this issue.

As with many new technologies, the cost of implementation is frequently recognised as a major barrier to BIM implementation. The perceived costs of implementing BIM technology include education and training costs, administration and start-up costs, and transition and behavioural costs. The increase in the implementation of BIM in the industry is mainly within large companies which have the resources while that cost can present a barrier to smaller firms which make up a large proportion of the industry (Hong, et al., 2016). This issue of cost forces investors and potential BIM adopters to consider the adoption of the technology very carefully (Allen Consulting Group, 2010).

Education and training costs have two elements in the adoption of any new technology: ensuring a company has the appropriately skilled personnel, either by hiring new staff or retraining existing staff in order to integrate BIM technology into its operations; and the retraining of existing staff to support the behavioural and organizational changes required to fully adopt BIM within the organisation's business model (Allen Consulting Group, 2010). Most BIM education and training available to date focus on the use of particular BIM software packages, with less attention to the deeper practical applications across an organisation's operations (NATSPEC, 2013). As a consequence of the lack of adequately trained BIM professionals in the sector, BIM implementation and use in the AEC industry has been hindered (Becerik-Gerber, et al., 2011).

Issues with BIM implementation at an organisational level include reluctance from senior managers to introduce new technologies and processes to the operations when management support for BIM implementation is essential for it to be a success (Ruikar, et al., 2005). Managers are concerned that the steep learning curve required to implement BIM successfully requires such resources that it will affect their business. The lack of knowledge of the transitional process from traditional practice to the successful implementation of BIM is clearly identified as a barrier (Aibinu & Venkatesh, 2014).

Addressing the legal aspects of BIM development is also necessary and intellectual property rights is a topic that has caused some nervousness around BIM (Mason, 2016). If owners pay for the architectural design of construction projects, they may claim ownership of the design documentation but licensing problems may arise when other

stakeholders contribute data that is integrated into BIM (Azhar, 2011). Determining who controls access to the BIM data and is thus responsible for inaccuracies is an aspect that could bring about a great deal of risk (Liu, et al., 2015). Stakeholders require security of confidential data in the BIM model, but a range of legal and security issues have been identified in connection with the administration of construction projects within an electronic environment (Chynoweth, et al., 2007). New legal solution will be required in order for BIM to be the vehicle by which project delivery is achieved (Mason, 2016).

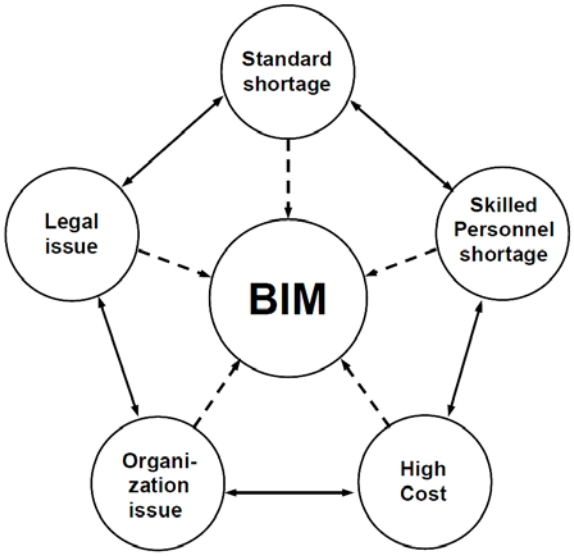

Figure 5: Relationship between main barriers of BIM (Liu, et al., 2015)

SUMMARY

The synergy between BIM and partnering is evident. Both approaches claim reduction in: project cost; project change costs; build time and dispute (Mason, 2017). It is estimated that BIM can eliminate unbudgeted change by 40%, and reduce the time to complete a project by7%, and the time to generate a cost estimate by up to 80% (Azhar, 2011). Modern AEC practices are moving towards a trend of collaboration. Outside of the design process this culture of collaboration has been impacting the larger industry — it's been slowly moving towards an integrated project delivery system where everyone works on a mutually accessible set of BIM models (Goubau, 2017).

The Architectural, Engineering, Construction, Facilities Management (AEC/FM) and Building Product Manufacturing (BPM) professions combine to be the biggest industry in the world, even bigger than either the automotive, aerospace or oil industries, yet the dollars spent per year per person in the AEC professions is the lowest compared to other industries (Neeley, 2008). The construction sector lacks the integration of stakeholders seen in other sectors which has been highlighted within industry reports for decades; the collection and sharing of information is almost inadequate so efficiencies are limited to the immediate individuals or organisation. A more collaborative approach is needed and the industry needs to feel that they need BIM to achieve this (Mason, 2016).

The construction phase stands to gain the most from full BIM implementation through simulation. Construction projects are a very complicated process, with hundreds or thousands of suppliers, contractors, and labour resources. Any construction conflict or dispute will find the client, architect, engineers, contractor and any number of sub-contractors halting work in order to any issue in order to be given a direction to proceed. By simulating the process on BIM, a huge percentage of conflict and inefficiencies can be highlighted prior to the expensive delivery phase of construction. Buildings will be constructed more quickly and managers can integrate design, construction, maintenance, and demolition data about building into a sophisticated model which assists all project stakeholders with improvements in performance efficiency while reducing costs, risk, waste, and carbon emissions (Liu, et al., 2015). BIM technology also leads to labour market improvements, encourages more collaborative working practices, and improves communication between project stakeholders (Allen Consulting Group, 2010).

The requirement of a collaborative environment and rich, sophisticated data sets for BIM to operate successfully is something that the Intelligent Contract concept could avail of. The need for all parties to work together, with a rich flow of transparent information between the parties would offer the right ingredients for the Intelligent Contract to thrive.

Chapter 3 - Analytical Literature Review of Smart Contracts and Beyond

SCOPE OF THE CHAPTER

This chapter will explore the concept of smart contracts and other relevant advancements that would complement the technology within the construction industry. It will give a brief history and evolution of the concept through an investigation on the available literature. The potential drivers and barriers to implementing the technology through BIM integration shall be explored and summarised.

DEFINITION OF A SMART CONTRACT

Smart contracts were first mentioned in 1994 by Nick Szabo. Szabo, a cryptographer, proposed the idea of embedding smart contracts into physical objects which he described as smart property. He defined a smart contract as:

"A computerised transaction protocol that executes the terms of a contract. The general objectives of smart contract design are to satisfy common contractual conditions (such as payments terms), minimise expectations and minimise the need for trusted intermediaries" (Szabo, 1994).

The effect of such contracts on contract law and economics, and their opportunities were said by their originator to be *"vast but little explored".* Szabo had a broader expectation for the smart contract concept that through specification of clear logic, and verification or enforcement through cryptographic protocols and other digital security mechanisms, smart contracts might offer an improvement over traditional contract law for efficiency in initiating contractual clauses that could be brought under the dominion of computer protocols. (Szabo, 1997)

Smart contracts have also been defined as 'Contracts that are fully executable without human intervention' (Morgan, 2014), or 'Self-enforcing, monitoring external inputs from trusted sources in order to settle according to the contracts stipulations' (Peters &

Panayi, 2015). The key characteristics of smart contracts were described by the (Norton Rose Fullbright, 2016) report:

- **Digital form**: it is in code form
- **Embedded**: contractual clauses (or equivalent functional outcomes) are embedded as code in hardware or software
- **Performance mediated by technological means**: the release of payments and other actions are enabled by technology and rules-based operations
- **Irrevocable**: once initiated, the outcomes for which a smart contract is encoded to perform cannot typically be stopped (unless an outcome depends on an unmet condition). It performs automatically.

The application of smart contracts in the financial sector would appear easier to establish given the relative straight forward nature of the instruments involved as oppose to the construction sector where every construction project is different, with a specific design and scope of works, this type of contract drafting is complex, and trying to account for all contingencies is not possible (Gronbaek, 2016). The general rule of thumb is that the longer the contract, the less straightforward its automation (Norton Rose Fullbright, 2016).

BLOCKCHAIN, CRYPTOCURRENCIES & BEYOND

The obvious evolution of Intelligent Contracts in maturing the level of automation is already well documented to be heavily linked with the development of blockchain technology and cryptocurrencies. This weighs heavily on the *Code is Law* concept (Wu, 2003) that has become popular following the widespread deployment of the internet and society's dependence on digital technologies which has seen technical regulations being enforced *ex ante* through code (De Filippi & Hassan, 2016).

Distributed ledger technology operates alongside crypto-currency and allows the Intelligent Contract to operate without the use of traditional payment arrangements and the interface of third parties such as financial institutions. Blockchain has been described as the fourth industrial revolution (Kemp, 2016). A blockchain is a ledger, or a database

of transactions recorded by a network of computers' (Peters & Panayi, 2015). Often referred to as distributed ledger technology, transactions are grouped in blocks and the chain forms the history of these transactions (the blockchain). It is widely believed to have been created as a way to distribute crypto-currency in a way that maintains publicly, and by multiple people a record of the transaction. (Mason, 2017)

The use of the blockchain has moved on from simply being the platform for crypto-currency, to ideas of cheaper transaction processing, crowdfunding and smart contracts. Blockchain "*holds promise for being the latest disruptive technology,"* (Peters & Panayi, 2015).

Blockchain-based Intelligent Contracts are not based on a central server (i.e. hub and spoke) but rather are distributed amongst a network of nodes. Blockchain-based Intelligent Contracts would therefore be more sophisticated, following the stigmergic ideology first coined by Pierre-Paul Grasse in his research on termites (Elliot, 2006), and qualify as computer software code that is autonomous and independent as it cannot be controlled by any one entity (Wright & De Filippi, 2015).

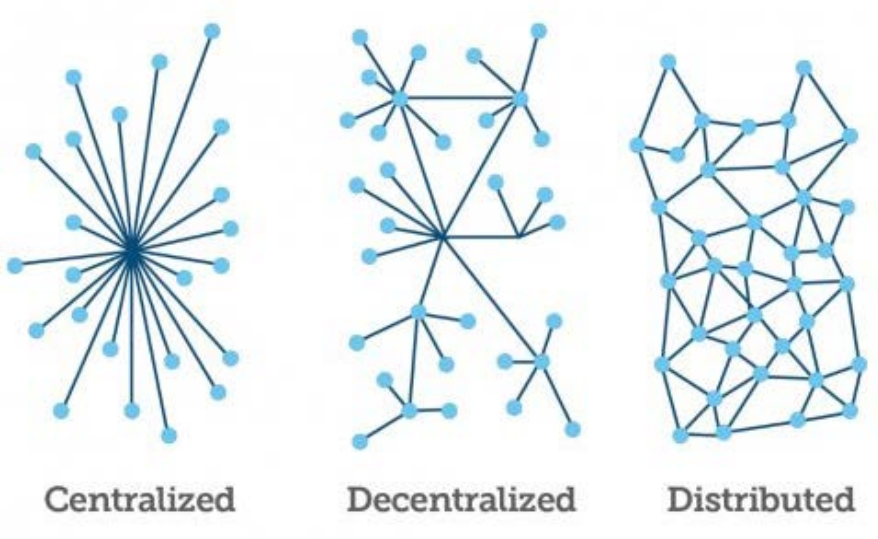

Figure 6. Centralised network vs a Decentralised network vs a Distributed network (Blockchain)

The blockchain concept was brought to prominence in 2008 when Satoshi Nakamoto published the white paper 'Bitcoin: A Peer-to-Peer Electronic Cash System' which based the Bitcoin crypto currency concept on blockchain technology.

Nakamoto's electronic payment system removed the need for trust in a singular third party and introduced a system based on cryptographic proof. In his whitepaper, he explained how the electronic bitcoin is defined as a chain of digital signatures; ownership is transferred by digitally signing a hash of the previous transaction and the public key to the next owner (Mason, 2017).

The social issues raised by these emerging technologies are enormous (Omohundro, 2014). The 'Internet of Things' (IoT) is predicted to rise to 26 billion devices and result in $1.9 trillion of economic value-add by 2020 (Gartner, 2013). Many are predicting the need for a corresponding 'Internet of Money' to manage the transactions between these devices will create the new economy for crypto currencies to thrive. This is likely to involve cryptocurrencies and smart contracts which will then come to interact with every area of our lives (Omohundro, 2014).

As these systems interact with the physical world, there will be a need for greater intelligence and real-world knowledge in making decisions. Artificial Intelligent (AI) systems will evolve to translate information from a wide variety of IoT sensors into precise terms that smart contracts can engage with. The legal codes of many countries have become quite complex and several AI projects are trying to create formal digital versions of legal codes as seen in Stanford's 'CodeX' project (Surden, 2012). These systems will eventually be used to resolve legal issues and perhaps even act as arbitrators or judges as more sophisticated AI systems with knowledge of the legal system will be used to help draft and simplify new legislation (Omohundro, 2014).

INTEGRATION WITH BIM

The latest pronouncement on the enablers for a digital age of construction have been reviewed recently (Mosey, et al., 2016). The proposition is that BIM enables, and depends upon, more integration and collaboration amongst the project team members. The merging of the two themes of technology and collaboration is in line with the UK

Government's 'Digital Built Britain' which seeks to create an advanced digital economy for the built environment, delivering high performing projects and excellent client value (HM Government, 2015). Intelligent, automated contracts can be seen as the logical progression for the Construction Sector to go digital (Mason, 2017).

The Intelligent Contract process will most likely rely on BIM as the platform from which to extract the necessary data it needs to run. BIM has been the most prominent advancement in the sector in recent years but a recent review of BIM concludes that there are still concerns over liability, the legalities of BIM and reliability of the software (Mosey, et al., 2016). For successful implementation of Intelligent Contracts, BIM Levels 2-6 take-up would appear necessary before wholescale contract automation stands a chance (Mason & Escott, 2017). BIM has been identified as the means to achieving the UK Government's Construction Strategy targets of lower costs, faster delivery, lower emissions and improvement in exports (NBS, 2016) however, the pathways of BIM and smart contracts are not necessarily interconnected. It is viable that smart contracts can remain at a pure transactional level for the more logical components of a construction contract (Mason & Escott, 2017).

As BIM allows design inconsistencies to be highlighted through clash detection, the different project designers' inputs can be resolved through simulation in the model before reaching the construction phase avoiding the problems that would be encountered in real time. This additional work in re-designing and the issue of whether this is treated as a claim would need to be addressed within any contract but addressing the issue prior to the construction phase certainly offers an advantage in mitigating exposure to all parties (Mason, 2017).

BARRIERS

The adoption of Intelligent Contracts will certainly have many challenges (Norton Rose Fullbright, 2016). A software program can in theory exist for many years yet it is inherently difficult to write coding intended for long durations when the external inputs required for the code to work may cease to exist (Mason, 2017).

The unalterable nature of Intelligent Contracts can also pose problem in terms of satisfying all parties that the coding is operating as intended. Confidentiality and the open nature of distributed ledger technology, should it be incorporated into the concept, pose information leaking challenges as does: storage constraints due to the enormous data requirements; software reliability; and compatibility issues will also require workable solutions and thorough simulation and testing and before wide-scale adoption of the technology is feasible in the industry (Mason, 2017).

A perceived lack of control and/or surrender to an automated third party in terms of the ability to act commercially has also been noted in (Mason & Escott, 2017). “The expectation for institutions to act against their vested interest is fanciful.” Commercial value for the sector must be high on the agenda of any Intelligent Contract solution.

The logical nature of Intelligent Contracts renders them unable to cope with ‘wriggle room’ type provisions commonly accepted as fundamental to construction contracts. A computer programme is made up of algorithms which are essentially “if this then this” of a ‘1 and 0’ binary nature. Commonly seen clauses such as ‘force majeure’ would be difficult to reduced to a set of logical algorithms (Mason, 2017). Creating sophisticated enough algorithms to handle force majeure and the other unexpected instances which are currently referred to the consideration of a human certifier is more difficult to imagine. This is seen to be the major obstacle in the adoption of Intelligent Contracts. While it is not impossible to think that artificial intelligence systems and sophisticated data analysis will one day provide a solution to catering for the unexpected, the question of whether such systems are evolved enough to give the required confidence is certainly a barrier to Intelligent Contract adoption.

SUMMARY

Intelligent Contracts appear to be the next logical extension to BIM whereby the contractual performance itself becomes automated or, at the very least, semi-automated. As the multi-party contracts such as the NEC3 and PPC2000 offer the ‘hub and spoke’ system of contract architecture, Intelligent Contracts would offer the next evolution of this model. However, Intelligent Contracts work best where they are of a short term nature

which is at odds with the complicated and long-running nature of construction projects. The logical network of mini contracts would form one seamless organic contract that can offer assurances in one of the largest problems within the construction Industry, *certainty of payment.* The nature of the Intelligent Contract is that it is an 'all-in or not-in' arrangement and through provisions such as a project bank account, or to take it a step further through cryptocurrency and blockchain technology, the 'pay when paid' arrangement would become an instantaneous transaction where all relevant parties are compensated as soon as the terms of the contract are met. There is no delay in the payment 'dribble down' effect through contractors to sub-contractors. Discrepancies between the scope of the contract clauses would be mitigated due to the bolt on nature of the Intelligent Contract model. The automation of contract administration, made possible by linking the Intelligent Contract to the BIM model, would offer accuracy and efficiency:

- The construction schedule could be a real-time tool directly warning of any possible contract issues from real-time data received;
- Variations could be predicted and identified earlier instigating notifications;
- The contract budget could be adjusted automatically and linked to the contract with notifications sent out to facilitate approval (Cardeira, 2017).

Embracing BIM and the ethos of 'Build it Twice' will be key to the success of Intelligent Contracts. An accurate BIM allows for a Bill of Quantities (BoQ) to be created more accurately, produced quicker and for less cost. Program and activity schedules can then interlink with the BoQ through algorithms which can further split the activities into smaller work packages. This breakdown structure would coincide with sub-contractor's 'plug-in' Intelligent Contracts. An independent certifier responsible for assessing the quality of work on behalf of the client could be used over some or all works as required. This maintains the human element in the process which would be desirable for acceptance in the short term by the industry. BIM and other technologies are intentionally disruptive but this 'stepping stone' approach gives professions the choice of evolving new roles for themselves. (Mason, 2017) This certification process could potentially be replicated by an appropriate sensor to further automate the process. The increased rate of technology in society today is undeniable with the number of sensors in devices set to pass 25 billion mark by 2020 (Gartner, 2013). The logical progression that sensors can report

back to a BIM model, allowing planned completion to be over-written with actual performance, as a more accurate digitised ‘as-built’.

As BIM and data management technology drive these new approaches in the construction industry, there will be a need not only to consider the contractual regime, but also to challenge the traditional competitive procurement and tendering processes with more collaborative structures and approaches. (Heywood, 2016). By using Blockchain and BIM in tandem, along with other quickly advancing technologies, there is an opportunity to create a leaner procurement methods which pushes the collaborative agenda. This will result in cost reductions by removing the multitude of intermediaries currently embroiled in the traditional process and will give a client greater control and transparency of cost, time and scope (Hughes, 2017).

BIM’s establishment appears to be a pre-cursor to Intelligent Contracts “in order to build a platform where the latter can operate” (Mason, 2017). The counter-argument that Intelligent Contracts would not need to align so closely with the BIM agenda due to basing themselves as not one multi-party contract but a collective of possibly thousands of contracts is also something to be considered (Mason, 2017). The harnessing of cryptocurrencies and blockchain technology could lead to the ultimate goal of yielding a fully automated intelligent construction contract, but at the very least offer protection to all parties from the insolvencies and late payments that have always plagued the industry (Cardeira, 2015).

The notion that Intelligent Contracts will be autonomously paying for performance based on data from a multitude of advanced sensors acting as a certifying authority will not be achieved overnight. The advances in BIM, in multi-party contracts, in project insurance can all be seen as building blocks for the type of paradigm shift required to achieve the utopian idea that construction can be a fully automated process. Technology must prove itself to be faultless for the required confidence to exist and trust in the system to be in place for the potential of Intelligent Contracts to be realised. Ultimately, addressing the current technological barriers is a waiting game for the technology to reach the stage in its maturity where it is indisputable from a legal perspective and the industry gains the required confidence in the ability to deliver alongside the other “good ideas” currently establishing themselves (Mason, 2017). For the Intelligent Contract concept to work, the

perception appears to be that trust needs to come before the business case. A phased based approach is the likely road-map and a semi-automated process could be developed using existing contractual procedures (Mason & Escott, 2017). The investigation of what processes in current contractual practices could be optimised through automation will be key to roadmap the path for the incremental steps towards a more automated future. Identification of the processes that would achieve the greatest cost/quality/time saving, while achieving confidence in the process, should make the concept more appetising for the industry.

Chapter 4 - Research Design and Methodology

SCOPE OF THE CHAPTER

This chapter analyses the research aims and objectives to establish a suitable research method and strategy. The research method will be analysed against the literature review to create suitable research questions and structures for the empirical data phase of the study.

The chapter will also contemplate ethics, and the underlying concepts to legal and scientific research methods. The limitations of the research will also be considered.

RESEARCH RATIONALE

The Literature Review is developed from several sources, including books, journals, reports, conference papers, Government publications, published surveys. Examples of this include the NBS 2015 survey, the Government Construction Strategy, International Journal of Project Management, and University of Western England's Construction Information Service database. Some unpublished papers and relevant thesis papers been used due to the scarcity of material specifically focusing on Intelligent Contracts in Construction.

The literature review:

- Gives commentary on the evolution and acceptance of collaborative working within the industry
- Introduces the concepts of BIM and how it has evolved over the years along with commentary on acceptance within the industry
- Describes and discusses the barriers and drivers of successful collaborative practices and BIM implementation
- Summarises the history of Smart Contracts along with the underlying principles and processes
- Explains the evolution of Smart Contract and associated technologies of blockchain, cryptocurrencies and artificial intelligence

- Commentary on the possibilities of basing the Intelligent Contract concept with the BIM platform
- Commentary on the current perceived barrier to implementing Intelligent Contracts in the Construction Industry

Doctrinal research is an obvious contrast to the typical research found in the natural sciences which generally seek to explain topics through the study of causal relationships between variables. Research on the natural and social sciences would commonly be based on the gathering of empirical data in which to either base or test a theory. Epistemologically, this varies greatly from interpretive and qualitative research found in legal doctrinal research. (Chynoweth, 2008)

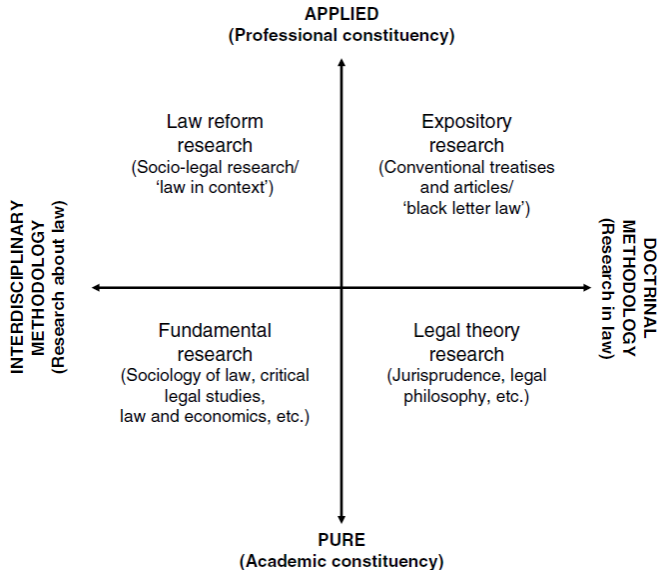

Figure 7 Legal research styles matrix (Arthurs, 1983)

The lack of the more disciplined, data based, research methodologies found in the social and natural science disciplines, and the reliance on the interpretive analysis and development of varying commentaries, is a particular feature of the arts and humanities family of disciplines of which law is part of. This shows law to be grouped at the 'soft' end of the spectrum in the well-known (Biglan, 1973) disciplinary model as seen in

Figure 8. This model shows how law as a discipline differs from other disciplines more dominant in the built environment. With the exception to design, the more familiar built environment disciplines of technology and economics belong in the applied and natural sciences. This science/arts & humanities contrast reflects the genuine epistemological and methodological differences found between the disciplines and their treatment of knowledge and learning. (Chynoweth, 2008)

This contrast of knowledge production was described by (Becher, 1987) where the cumulative accumulation of knowledge, over time, contributes to an overall comprehensive explanation of a particular phenomenon in the sciences. He describes the development of knowledge within the arts and humanities disciplines as an ongoing process of reiterative enquiry which seeks, not to explain the individual components of phenomena but, to develop an overarching understanding of their complexity.

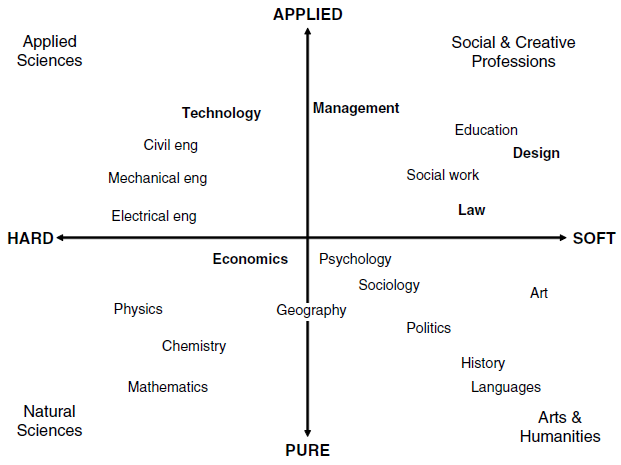

Figure 8 Disciplinary model (Biglan, 1973)

While the law and construction disciplines have methodological and epistemological differences, interdisciplinary or socio-legal research broadens legal discourse in terms of its theoretical and conceptual framework (Brook, 2014).

RESEARCH METHODOLOGY

The research methodology for this study sits in the socio-legal tradition and utilises an interdisciplinary methodology as it references external factors and context. “The socio-legal discipline describes the point where the epistemological nature of research changes from that of an internal enquiry into the meaning of the law to that of external enquiry into the law as a social entity” (Chynoweth, 2008). The epistemological nature of this research is that of external enquiry into law as a social entity. It is research about law, rather than research in law. It is only through investigating subject’s perceptions into any phenomena, within socio-legal tradition, that the truth is observable. The value in observing these views is accentuated further when the subject matter is the cutting edge and polarising topic of technology and the disruptive change it would have on the traditional approaches of the construction industry (Mason & Escott, 2017).

(Fellows & Liu, 2015) describe qualitative research as a means to gain insight into people’s perceptions, events or shifts in thinking. This style of analysis is perceived to be a more holistic approach to data gathering with results that are open to individual interpretation (Denscombe, 2014).

Qualitative analysis is not subject to specific analytic techniques as it requires interpretation of statements and opinions formed around the data collected (Dale, 2016). The research focuses on the qualitative data to understand people’s perceptions of the existing contract and BIM environment in the industry in order to discuss the possibility for Intelligent Contract implementation. The views and perceptions of interviewees forms the backbone of this study. The discussion section in the following chapter records the sentiments and views expressed in the respondents’ own words.

Empirical research has been collected to support the findings in the Literature Review and develop a practical understanding of the technologies. Due to the embryonic nature of the subject, case studies were not found to exist. Primary research will be collected through selected interviews from a cross section of the construction industry. A base questionnaire was developed in order to provide consistencies with the interviews but this acted as a guide as each subject offered specific focus for discussion due to the differing backgrounds of the chosen subjects. Access to a large network in a range of professions across the Sydney construction industry, along with the willingness of

interviewees from further afield has been largely accommodated from my work as a client-based Senior Project Manager.

The decision to focus the data collection on a chosen selection of sources is due to the incipient nature of the subject. The alternative strategy of collecting data from a larger uncontrolled group would have resulted in more generalised and unreliable response due to the limited knowledge of the subject matter. The external validity of this method can also be a limitation due to the disconnect from what people convey in a survey compared to their actions. The lack of correlation between attitude and actual behaviour is notorious (Erwin, 2001). Adopting a post-positivism philosophy, by pursuing objectivity through recognising the possible effects of biases, this research bases itself on the principle that there is an objective world but knowledge of it is filtered through the subjective experiences of individuals. Knowledge is, by its nature, partial and bound by individual experience (Brook, 2014).

A hypothesis approach is also used in this paper in line with the concept of Socratic logic in that a correct statement is one incapable of being rationally contradicted (De Botton, 2001). The mere fact that a majority view can exist that full automation may not be possible in the construction contract does not deem the subject to be final and absolute. The exceptions and opportunities described by the respondents during the investigative process provide the context for the debate to become more focused on the drivers and limitations that can be exploited in further research (Mason & Escott, 2017).

RESEARCH LIMITATIONS

The research is limited due to the embryonic nature of the subject and lack of real world application of the Intelligent Contract technology in construction. This paper will investigate theoretical and conjectural literature based on cutting edge ideologies and commentate on the possible applications within construction.

The interview process used instigates discussion rather than hard data. This may mean that answers are skewed, with interviewee's responses being tainted by the author's own viewpoint. A certain decorum of separation from the issue must exist in order to collect accurate data while maintaining the flow of discussion.

Also, there is a risk in that the respondents do not have enough personal experience to be able to give the sufficient feedback necessary. As the subject matter is extremely theoretical, the most effective responses will be from a senior management level, who can be more difficult to access. This has hopefully been mitigated by the high calibre of relevant interviewees that has been secured. Sub-contractors and suppliers are harder to directly access and while their feedback on the subject would be welcome, the subject is still in its infancy and the value, from what would be an arduous process in gathering adequate data from this end of the Construction Industry spectrum, would be minimal.

The time constraints associated with a dissertation of this level also limits the time spent gathering empirical data. A research project of this level does not often achieve a static representation of the target data (Denscombe, 2014).

The disruptive nature of the topic may require subjects to be critical of their own way of working. This may result in answers becoming skewed, with respondent's perceptions being tainted by a natural bias to their own point of view or overly anchored to their preconceptions of what is seen as current industry best practice; people that believe in collaboration are more likely to respond positively (Dale, 2016).

RESEARCH ETHICS

Interviewees were required to give consent and were made fully aware of the research aims at the start of the process. As (Fellows & Liu, 2015) states, consent should be free from coercion and manipulation and the subject should retain the right to withdraw or retract any or all of their input at any time.

Throughout the process anonymity has been given when the interviewees have requested. This has encouraged a more honest and frank discussion as exposure of commercial or confidentially sensitive material has been avoided. Data protection is an important ethical requirement albeit a legal requirement and any information regarding a living person will be subject to the Data Protection Act (1998) (Dale, 2016).

Chapter 5 – Results and Discussion

SCOPE OF THE CHAPTER

This chapter presents the results of the empirical research. Commentary on the data will validate the findings against itself (other interviewees) and the quantitative data from previous chapters.

THE INTERVIEWEES

The following professionals were included in the interview process:

Reference	Name	Area of Expertise
TT	Thomas Trinelle	A Software developer working in the AEC & BIM development field for flux.io
CC	Chris Canham	A Commercial Director for Aecom and former Head of BIM Development for a global construction/development company
SC	Shen Chiu	A Development Director for Investa property group
JL	Justin Lipton	The Founder of Exari. A contract software company specialising in Artificial Intelligence
AA	Requested anonymity	The Managing Director of a construction dispute resolution firm
HC	Helder Cardiera	An experienced Project Director with an Architect/Quantity Surveyor background who has also published papers on smart contracts in construction
DR	David Rayment	A Barrister specialising in construction litigation

THE CONSTRUCTION INDUSTRY

The construction industry is a very fragmented sector with poor efficiency across all aspects of the development cycle. While production rates have remained the same wages and resources have increased (McNamara, 2002). Unless we embrace new technologies to increase productivity the industry will struggle. By embracing new technologies greater value can be harnessed through the procurement process by opening up a global supply chain network.

“If we don’t improve efficiency and productivity. Streamline global supply chain and embrace technology we will continue to fail. I'm waiting for the tech sector, someone like Google or an Elon Musk to come in and take over" CC

The perceived lack of collaboration and penchant for litigation was also exhibited by the following responses.

"The industry by nature has to collaborate, which doesn't necessarily happen." HC

"There are a lot of conscientious builders who are anxious to comply with legislation but there is also a large number who make more money by not complying and dealing with issues as and when they happen." DR

"Law firms are known to devalue their engagement agreement, within the construction industry, because they know they will make up the income in litigation fees." JL

CONSTRUCTION CONTRACTS

The general consensus between all interviewees was that current construction contracts are merely used as a weapon which predominantly favoured the bigger player. It was seen a reactive tool to be used when situations occurred.

"We see contracts as an adversarial tool. The only time a contract comes out is if the relationship has broken down and you have to refer to the 'rulebook'." CC

"The very nature of the industry is that there are many unknown variables for which the contract is then used as a weapon when situations present themselves. My experience of construction contracts is that they are generally rather one-sided. Smaller contractors don't seem to be very aware which plays into the hands of the bigger players who often dictate onerous terms." DR

Inconsistency and ambiguity of construction contracts was also identified as a major factor for the adversarial environment within the sector.

"Inconsistencies and ambiguity is also a problem. Lawyers like open loops in contracts as it gives them angles wiggle room to work with in court. The biggest factor in most

disputes is the interpretation of the wording. People tend to interpret to serve their own purpose even if they know they are potentially wrong as they play the percentages in winning through dispute resolution." CC

"There is too much ambiguity in contracts which people use to lay challenges and claims." HC

"Discrepancies between 'back to back' contracts can cause issues due to inconsistency." JL

This is seen as a major flaw in the drafting of contracts in not only the primary contract but the bolt on sub-contracts. Clarity of terms and a less legalese approach to drafting would mitigate this factor, but the human element involved in administrating the contract would still offer exposure to miss-interpretation.

"Plain English is a whole movement in law now." DR

The onerous nature of administering contract in current practice was also a shared opinion. For instance. in a dispute situation where there has been a delay on site, the workflows and waterfall aspect of notifications and responses was something that was identified as being receptive to automation in order to mitigate human error in what can be an onerous activity.

"Construction contracts are certainly administratively onerous." DR

"The Intelligent Contract concept would certainly add huge administrative efficiencies and reduce disputes that arise from human errors or poor judgement." DR

"The automatic input of data and increased level of data capture would certainly reduce the human error factor" AA

Automating data collection and processing for other contract administration tasks was another benefit discussed that Intelligent Contracts could potentially perform.

“The requirement to make changes to contract documents when legislative or regulatory changes happen can be very onerous. Speed of reaction to any real-time scenario is key to success for any business. A digitized contract will add an advantage." JL

"*The link of the BIM data flowing back and forth between the Intelligent Contract would certainly reduce the manpower required to run the same processes manually."* AA

RISK

Defining risk is tantamount to success in many industries, none more so than in construction.

“The biggest issue on any project is the identification and understanding of risk.” AA

"Risk is key to all industries. In construction, the goal seems to be all about de-risking the possibility of litigation." JL

"Adversarial behaviour is all driven around risk. Everyone is trying to protect their patch, which is important but it becomes a problem when it becomes ones sided. Which is common." CC

By shifting an organisation to a model based cost plan, it would allow more effort to be spent on the tendering process which in turn will allow greater definition of risk. The BIM details the project to a far greater level which allows greater confidence in pricing and analysis of risk so rudimentary figures aren't added by contractors just to cover unknown variables.

"Does BIM manage risk better? Yes, it does. However, there is cultural change needed at grass roots and management level that it just stalls presently." CC

"The openness and wording of contracts is all about managing risks" AA

Intelligent Contracts will be more transparent and afford greater determination of risk, therefore making it more straightforward to assign the risk through negotiation. This will simplify negotiations and place parties on a more level playing field. Traditional contract negotiations are facilitated through rigorous back and forth communications, which requires large resources and assumes each party is sophisticated and advanced as each other which is rarely the case.

"*Intelligent Contracts will reduce administrative requirements and could reduce the scope of there being a dispute due to the more efficient and collaborative nature of the program* but a*re they going to be any more certain than a traditional contract? There is no reason in principle that I can see."* DR

This is essentially true, but it's the automation of the process that will add value and reduce minor dispute. Clash detection in this system would be far superior. An Intelligent Contract forces the execution of the contract. If parties wish to act illegitimately they will have to do so retrospectively which of course makes it harder.

DISPUTE MANAGEMENT

By having a more logical and defined dispute procedure that would be initiated automatically and have higher management (or separate teams at the least) handle dispute resolution instead of the site based teams, greater efficiency and momentum could also be created on projects. This could avoid what can sometimes be an emotional negotiation at site level which can exacerbate issues.

"*Project Managers and site staff should ideally concentrate on doing what they do best which is the project management of the project. Resolution of contentious issues is a skillset in its own right and the project team needs to concentrate on project delivery."* AA

Making the Intelligent Contract act as a central data point that all data flows to, from the BIM model and program schedules etc, will result in the opportunity for real time analysis to take place which allows trends, clashes and potential problems to be flagged early. Intelligent Contracts will ultimately highlight situations earlier as it will rely on pre-agreed logic (at an organisational level) and not individual judgement.

"Early detection, communication and intervention is beneficial to reducing disputes. I would imagine that the Intelligent Contract could be used to work with the contract program to highlight issues on a project." AA

In any dispute or grievance, the audibility of data is considered paramount to correctly resolving the situation.

"With any dispute, audibility is key." JL

"*Blockchain would add validity to any process*" CC

As the Intelligent Contract software will be central to all communications and contractual actions it will be able to provide a concise central auditable ledger of all communications and actions during the lifecycle of any contract. This is already seen in the flux.io workflow software. For larger or more complex projects, blockchain technology could compliment the validity of this process.

"Whenever anything goes through flux, the action is timestamped and captured. Metadata is assigned to each action making a rolling ledger of actions. A notification system is also available where rules can be set to allow for notifications being sent out when set-rules are met." TT

REQUIREMENTS FOR INTELLIGENT CONTRACT IMPLEMENTATION

While the discussion covered the many merits of the Intelligent Contract process many obstacles for the concept were also raised. Some were obstacles, such as data security and industry confidence, while others were stipulated as pre-cursors required for the technology to operate. Sophistication of the data available was a very evident under-current during these interviews as the point of quality outputs being reliant on quality inputs was reinforced time and again.

"The commercial agreement between main and sub-contractor needs to be protected as the information can be used as a competitive advantage. The system would need to be rigorously tested, proven and fool proof." HC

"When you start building collaborative platforms you have be able to define the levels of access to all data, so users only have access to relevant data sets." TT

Separation of sensitive and/or commercial data for ‘bolt-on’ intelligent subcontracts would need to be considered in the data access protocols of any Intelligent Contract in order to maintain data protection.

The automation of contract clauses aren't the only considerations for the Intelligent Contract. A major hurdle will be in translating and 'digitising' the scope of works and specifications in order for it to co-ordinate with the Intelligent Contract protocols. On any projects, these can be extremely complex and have a sheer magnitude of data. This is perhaps where a more advanced BIM evolvement would be required as the scope and specs could be mostly taken out of the BIM. Standardisation of specifications and construction methodologies would also help in building a database of acceptable protocols and any amendments for these standards can also be easily updated when they occur, with any consequences captured through analysis. By digitising the scope as well, clash detection can highlight where there may be contradictions within the contract documents and even shortcomings against legislative standards and specifications

"The defined scope of work needs to be as detailed as the general conditions…generally, a standardised set of general terms and conditions can be a good idea but a project would have an individual scope of work, specification and departures from the general terms. Would an issue arise where a complex specification and scope of work has only a limited amount of time to be translated into a Intelligent Contract?" AA

The extra emphasis and the effort required at the front end of Intelligent Contract projects would also require a cultural shift to having more evolved information early in the construction process. Ultimately, by producing a less complex and convoluted Intelligent Contract which is accepted more as a standard could mitigate this and could eventually speed up the process.

"Contracts take a long time to finalise and adding another hurdle to this process would be a huge obstacle." SC

"The Intelligent Contract concept will definitely create more 'up front' work for the legal profession as the nature of construction contracts are that terms are generally negotiated back and forth." JL

DATA REQUIREMENTS AND PAYMENT MANAGEMENT

A major point for discussion during all interviews was that the required data to run an Intelligent Contract would go beyond what was potentially available within a BIM model. The consensus that, while BIM could provide data for the physical asset of a design, there are more variables needing to be considered during the construction phase.

"The BIM model is'nt the only thing that costs will be based on. Prelims, supervision, margins etc are not a physical entity and must be considered also. The construction program (not the contract program) would need to be robust, so it's not just the BIM that must be considered. Is the program going to be representative of what goes on on-site and accepted by both the client and builder?" SC

Table 4, below, shows % of total construction contract value of what is measurable using BIM (note: this is generic and will vary dependant on project requirement) so will range based on an actual project. (Courtesy of SC's internal company investigation)

Item	Description	(Included/Not Included) in 5D BIM measure	%	Range
A	Demo, Excavation, site retention	N	10%	5%-10%
B	Trade Works (Materials)	Y	45%	40%-50%
C	Trade Works (Labour)	N	25%	20%-30%
D	Prelims & Supervision	N	13.5%	18%-23% (CBD)
E	Project & Design Management	N	1%	
F	Design	N	2%	
G	Margin	N	3.5%	
			100%	

Table 4: Percentage of construction cost measurable against BIM

You can see from the table, BIM only models ~45% of the total construction cost, so it would not be possible to fully automate claims based on the BIM status against programme alone.

"The BIM model would obviously have to be very sophisticated in that not only components but also other influencing works be captured and related back to any payment claim from the model." AA

Not only would every element have to be captured but each component/activity/task's relationship, if any, to other cost items or components in the BIM would need to be considered. Every element could be broken up into procurement, delivery and install to allow stage payments for each cost item if required.

The extra sophistication of not only the BIM data but also the program and cost model will require any contractor to be more transparent due to the reliance on the accuracy of the program and BIM model to base payments on. This would be onerous on the contractor which could be an obstacle.

"One of the freedoms on the contractor side is to have flexibility in their own program. Is there an onerous task on them to change the BIM model & schedule?" AA

"Transparency of program would be an issue as the builder would be unwilling to give up the 'fat' he has built in his program or be held accountable when forced to accelerate or add resources if it is anyway out of synch." SC

The alignment of payment claims to cost models would result in greater detail needed at the procurement stage. This will again be more onerous for the contractor and one would hope the value in doing so would be realised.

"The procurement strategy must be a heavy consideration and the cost breakdown must be heavily detailed and broken down to allow the payment structure to match. If a there is a discrepancy between the payment schedule given to the sub-contractor and the one received by him then the system falls down." SC

"It builds in a commercial necessity that identifies each task that needs to be carried out for payments to be made." DR

This is no different to a traditional contract but an Intelligent Contract will guarantee payment the minute the verification function has been met. This reduces the option for

non-payment over a justifiable invoice. Monthly payments could still be maintained but the 'inch-stone' check off of components will happen on a more regular basis which can give a far clearer picture of any project in a real-time situation.

"*If the Intelligent Contract can enforce the payment regime it would be attractive as, if this way of business could be achieved, there would be a whole raft of small firms in the industry which could flourish under the confidence of being paid. Contractors may initially push back on instant payments as they like to hold funds and use it as capitol for other projects etc* " CC

"*Guaranteed payment would be a huge step but trust in the technology has to be present. Confidence in the system would be key*." HC

"*I've seen developers claim early costs within the nuts and bolts costs in order to get ahead on cashflow*." DR

This is common practice in order for the contractor to get ahead on cash flow to 'fund' the build. Banks are unwilling to release funds with no collateral due to the lack of security over a physical asset that the costs are related to. This is also due to the longer payment terms in the industry. An Intelligent Contract would help by optimising payments and reducing delay which would negate the need for contractors to continue this practice. It will create a more justifiable environment for payment which satisfies the bank and developer while the increase in payment speed would assist the contractor.

DATA ANALYSIS

Once the hurdle of requiring a high level of data capture has been achieved, tremendous value can be added through the analysis of data.

"One of the thing that our industry hasn't done well is capture data. It's the predictive analysis of data and forecasting that will be the goal that will add huge value." CC

TT gave an excellent example of what can be achieved through automating a process with high level data and analysis.

"An interesting project we did was to produce a crane management program for a construction project. This took the 2d view of the building and site while mining the structural data from the Revit model and taking into account the construction schedule. A logistic schedule for structural steel delivery was produced based on where the user placed a crane on the site plan. This was obviously only set up once, so any change from weather or material/construction delay or merely to optimise crane location was able to be done immediately by simply changing parameters in the program. This even plugged into weather data to allow for wind restrictions." TT

The value that can be added on to the Intelligent Contract concept through the sophistication of data input it would demand would open the door to endless forecasting and optimisation opportunities that would add huge efficiency to any project.

"AI is very much on our radar. It could be used for object recognition, safety tracking, audits and insights on issue resolution or clash tracking. It could create predictive models for contractor procurement, organisational process and structure. Predictive modelling on all sorts of construction data analytics from contractor performance to resourcing." TT

BIM INTEGRATION AND INNOVATION

During all discussions, it became evident that the perception was that BIM has not become the indispensable tool that may be required for the Intelligent concept to succeed.

"BIM hasn't really proven a real tangible value to the whole industry. It's just being used as a marketing strategy at the moment." HC

"BIM in the UK hasn't been as successful as it should have been. It has been more of a marketing tool with the exception of some government projects where value has been documented" CC

It seems that, while companies are 'ticking the box' of BIM usage for marketing and even some regulatory purposes, it's true potential is not being harnessed and the goal of the BIM being used in asset operation at a large scale is a long way off yet.

"The operators of buildings are not using the BIM models for operations (not usually the government agency. Being a sceptic, this is down to them losing out on fees by using what would be a far more cost-efficient method where they would get less margin from the owner. There is no incentive there and there not at the place yet where they offer the more valuable service to win more work" CC

"The real goal for BIM is building operations, which will be huge but is a while off yet." TT

Even when BIM is being used by some contractors, if only some project stakeholders are involved in the process it negates the advantages BIM brings even during the design stage where clash detection is the main advantage.

"Regularly the design is handed over at 70% design. If this is then handed to the contractor or sub-contractors who doesn't use BIM, then clash detection for subsequent changes can't even happen" HC

Given that the reputation for innovation is not endemic in the Construction Sector (McNamara, 2002) it is a shared opinion that it is the sheer magnitude of the industry which makes it difficult for new innovations to be adapted.

"Given the magnitude of the construction sector, it is very hard to introduce any new innovation." JL

With that being considered, it is still clear that the attitude towards change and innovation is still lacking.

"The fear of the unknown is a real obstacle. The UK and US government had to drag the industry to BIM. The industry wasn't going there itself." CC

"The approach to innovation is very pragmatic or granular with no real consideration for long term goals. It must add immediate value in time, quality or cost. In the US, BIM adoption has purely been through demonstrating ROI as it hasn't been mandated. BIM

hasn't necessarily taken off quite yet but the curiosity within the industry for new innovation has definitely increased." TT

The main driver for implementing any innovation within the industry seems to be more short term focused and demanding of immediate Return On Investment (ROI) in either cost, time or quality.

"For any innovation to be picked up in the construction industry, the benefits have to be very clear. If the benefits are tangible." HC

"The construction industry is very operational and the margins are very small which gives little scope for R&D investment." TT

Where organisations have implemented innovative practices or technologies, it appears to be the more agile, middle-tier players that have spearheaded change.

"The low tiers can't afford it. The top tiers are too established in their own paradigm and cultural behaviours. The mid-tier wants to be the big boys and are more motivated to be nimble and to adapt change and embrace new technologies." CC

This insight led to a more widespread discussion about who in the industry would be best placed to champion the Intelligent Contract concept.

"Developer/builder companies would be the best to trial the concept due the drive for efficiencies between the two partner companies. It will be very difficult to get a private developer and separate private builder willing to be so transparent. Government agencies could enforce this, but unless there is a very clear, trialled solution the concept is rife to have holes and problems in the early stages of the concept." SC

"The finance side of projects may one of the main drivers for Intelligent Contracts." HC

"Intelligent Contracts would certainly improve the relationship between the financiers (banks), the developers and the builder. There is an uneasy relationship paradigm between these parties due to the defensive attitudes required and the miss-alignment of the parties interests." DR

The opinion that the finance stakeholders in projects would be drivers for Intelligent Contracts due to the opportunity to de-risk the construction process through a more efficient and transparent contract mechanism was not surprising. The upside for a financer of having greater confidence and real-time analysis on the state of a project would mitigate many risks to an investment. The opinion that it developer/contractors would be best placed to implement an Intelligent Contract makes sense due to the openness and transparency of data required for the concept to succeed.

Chapter 6 – Results and Discussion

SCOPE OF THE CHAPTER

This chapter summarises the major findings and contribution of the research against the initial hypothesis proposed while also reflecting on the limitations of the research. Conclusions and recommendations for further research will be proposed.

SUMMARY OF HYPOTHESIS TESTING RESULTS

Table 5 summarises the results of the hypothesis.

Hypothesis	Results
Hypothesis 1: By creating an all-encompassing contract process - that: ensures all parties adhere to the terms agreed; which offers protection of payment, insurance and data; as well as the potential to increase efficiency and reduce risk - it should make the successful implementation of Intelligent Contracts the top priority for the Construction Industry. The first step to making this possible would be to build on the momentum that the BIM agenda has created and to compliment the BIM platform before evolving into further technologies.	The research justifies this hypothesis. The consensus that the Construction Industry is far behind the evolutionary curve seen in other industries in recent decades is evident. The soft approach in the collaborative agendas pushed in the last 20 years has seen minimal impact and BIM is struggling to gain traction at a large scale. A more disruptive change is needed to build on the inroads these agendas have made and an alignment with the BIM platform would certainly offer a springboard into fully digitizing the Sector through Intelligent Contracts.
Hypothesis 2: The industry is nowhere near mature enough to facilitate such a disruptive technology that would essentially change the way construction projects are run. Attitudes to streamline the procurement and contract process are that projects are far too complex to simplify into what would essentially be a manufacturing model and the appetite to change does not exist across enough of the industry to succeed.	The research partially supports this hypothesis. While the industry has not been overly proactive in the pursuit of collaboration, in the trenches, the tide is turning. People realise more than ever the impact technology has on every facet of society and that if the Sector doesn't embrace the digital age, it will get left behind. The industry is currently not mature enough, but an appetite is beginning to form.

Hypothesis 3: The level of BIM usage and the capabilities of the major platforms are not at a stage yet where the platform could be harnessed to facilitate the implementation of Intelligent Contracts. Potential user numbers would not be viable and technology capabilities are not sophisticated enough.	The research partially supports this hypothesis. BIM has not been adopted by all players in the industry over many factors. This has restricted the development of BIM to bring it to a level where the Intelligent Contract concept could flourish. This is slowly changing however as more government agencies are mandating the technology which is dragging the industry into a BIM reliant built environment. More easily attainable value is required to be shown to the industry for not only the BIM agenda but any proposed technology including Intelligent Contracts.

Table 5: Summary of Hypothesis Testing Results

CONCLUSION

Construction is both an art and a science. Most construction projects can be classified as prototypes as they will only ever be built once and not replicated. It is probably one of the most de-centralised industry in the world due to the sheer volume of stakeholders involved in any given project which makes it extremely complex. As a consequence the modern builder is more sophisticated and generally more collaborative in nature. Modern builders are more evolved in the design aspect of projects which would not have been as prevalent years ago. However, the margins within the construction sector is so low and the industry has not improved production rates enough, adding to the already adversarial nature of the culture where people have to fight over de-risking their position.

By offering a different approach that will demand transparency and collaboration therefore de-risking the industry, people will open up and be able to operate in a more collaborative and transparent fashion leading to global supply chains and gains in efficiencies. Clients will have more certainty over the delivery of the project. In traditional practice, every contractor and sub-contractor and even the client adds contingency to cover risk on a project which carries a monetary figure. On large projects, this adds up to a huge sum. For the level of effort and risk, construction isn't an attractive investment.

The Intelligent Contract is a process that will rely on the quality of the data being inputted. The requirement to have a certain flexibility within the process until it accepted as infallible would have to be intrinsic to the phased implementation of the technology. An Intelligent Contract would likely be linked to a sophisticated BIM model with inputs for costing and program required to capture all necessary data. In the initial stages, it wouldn't have to necessarily work in real-time or in short timeframes but as the technology would evolve, real value could be garnered from the analysis of real time project data. Whichever way construction projects are run in the future, the Intelligent Contract would have to align. This is looking most likely to be the BIM process. The fact that BIM is already regulated by a set of standards will help this establishment due to offering a more standard and stable platform that already has Industry buy in.

"I see the concept of Intelligent Contracts taking off if BIM starts to take off and go mainstream." HC

The extent of which an Intelligent Contract will be able to accommodate its own dispute determination and the requirement to sign over to an automated determination or process is where the lawyers may get nervous. This fully automotive process may ultimately be the goal but the industry would have to be far more evolved for this to be achieved but an objective means of assessing performance that is consistent and knowable should be the goal. An AI driven mechanism for dispute determination would certainly be innovative.

"The concept relies on other technologies to be evolved and more mainstream in the industry." HC

The benefits to be made from an Intelligent Contract could be seismic. Greater administrative efficiency would reduce costs and lead to less minor disputes. Surety of payment would lead to more small companies being able to operate with confidence in the sector. Transparency of contract terms would drive collaboration and make the industry more attractive to all stakeholders' due to the greater definition of risk within any project. The input required from all players in the Sector is equally colossal to make the concept a success. To create an environment where the sophistication of data exists from all stakeholders that will be the fuel for a central Intelligent Contract system, will require a huge step in the digitisation of the industry. BIM has instigated this but a tipping

point must be reached in order for the Industry to surrender to its inevitable switch over to the fully automated digital age. The Intelligent Contract will be more than the reference document that current contracts are used as, it will be a tool to be used central to the construction process.

RESEARCH RECOMMENDATIONS

In putting any proposal together for something that would be so disruptive, it will be important to talk to a huge cross-section of the industry due to the vastness and complexities of the sector. Due to the all-encompassing approach the concept would create, it is important that the research behind it matches the magnitude of the task. People are very much restricted to their own experiences and would not be able to advise on different aspects of the industry. In order to propose what could be a one stop solution for a whole sector, a solution for all eventualities must be considered. All procurement methods, professions and stakeholders from different aspects and phases of the development cycle along with people with general experience over broader aspects of the sector should be considered.

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