# Intelligent Contracts and the Construction Industry

Dr Jim Mason, Department of Architecture and Built Environment, University of the West of England, Coldharbour Road, Bristol, BS16 1QY. Jim.mason@uwe.ac.uk

## Abstract

Advances in technology have resulted in a fast changing landscape for construction contracts. Lawyers struggle to keep up with the pace of innovation and the need to provide legal solutions and accommodate new approaches. Building Information Modelling (BIM) has become part of the common parlance in construction notwithstanding limited evidence of its impact on the ground... Intelligent contracts appear as a logical extension to BIM whereby the contractual performance itself becomes automated. However, intelligent contracts work best where they are short term or are of instantaneous effect. This is at odds with the complicated and long-running nature of construction projects. Further, storage constraints, compatibility and reliability issues together with confidentiality and the long term nature of distributed ledgers pose additional problems. The aim of this paper is to present the debate about what could be achieved in the construction industry by the adoption of intelligent contracts. An on-line forum provided the secondary data on which the discussion is based. The objectives are to introduce aspects of technological advancement within commerce generally and to discuss their application in construction. The hypothesis advanced is that certain aspects of the construction contract cannot be fully intelligent and the best that can be achieved in the short to medium term is a semi-automated position. Further, intelligent contracts should be viewed as part of the BIM-led revolution in construction and not separate from it. The recommendation is that incremental advances such as the

coding of project management and contract administration data be targeted to provide improved operational efficiency and value savings.

Key words: Smart contracts, BIM, Intelligent contracts, Technology, Automated construction process, Construction Law.

Introduction

The pace of change currently discernible within the construction industry appears unprecedented. In the United Kingdom the standard form contract providers stand at cross-roads of accepting multi-party contracts as the way forward (Saxon, 2016). The Government Construction Strategy 2016-2020[i] and Digital Built Britain[ii] initiatives encourage technological advancement in all areas. The role of law in relation to these new developments is to facilitate and accommodate (Mason, 2016). The developments and trends studied in the last decade have centred on partnering arrangements (Mason, 2007) and issues such as the concretising of the duty of good faith (Mason, 2007). The stumbling block preventing these initiatives from taking a firm hold has been the intransigence of the key players in the construction industry and an all too common reference to human nature being against anything resembling a cultural shift away from the distrustful approach adopted by many. The mere term "business ethics" has been deemed an oxymoron (Mason, 2009).

The landscape has now shifted away from partnering and the body of work supporting its adoption. The work done by the author to date has not explored the potential that exists around intelligent contracts which is addressed here for the first time. In the last 30 years advances in 3D-CAD technologies have provided the opportunity to use a 3D model to manage construction information (Wang et al, 2004). The logical advancement of these tools is into 4D to include the demonstration of the entire construction progress. The animation challenges of such representations have been successfully addressed (Kamat et al, 2001). BIM is making headway and the legal groundwork is being put into place to facilitate level 3 take up (Mosey et al, 2016). BIM is of interest to construction lawyers

who can define and address the challenges it poses to established practice and how they need to be tackled (Currie, 2014). However, the area of particular fascination for construction lawyers if further down the road of technological advancement. The key legal document itself – the contract - has the potential to become automated. When the contract itself becomes centre stage then the lawyers' involvement is no longer at the periphery. The fundamentals of law come into focus and the subject becomes that much more compelling for the construction lawyers involved.

The aim of this paper is to scope out how intelligent contracts might be used in the construction industry and the resulting benefits. The objectives are to explore aspects of technological advancement and existing good practice which can be used to facilitate their adoption. . The hypothesis advanced is that certain aspects of the construction contract cannot be truly "intelligent" at least in the short and medium term and the best that can be achieved is a semi-automated position.

## Background

The term *"smart contract"* was coined in 1994 by Nick Szabo, a cryptographer who defined it 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"*.

The key characteristics of smart contracts have been described as being (Norton Rose Fulbright, 2016): it is in digital form and is embedded as code in hardware and software. The performance of the contract and the release of payments and other actions are enabled by technology and rules-based operations. Lastly, the smart contract is irrevocable as once initiated, the outcomes for which a smart contract is encoded to perform cannot typically be stopped. Performance is automatic.

The term intelligent contract is preferred in this paper. Smart contracts in the United Kingdom denotes a process where a contract is made with the help of a computer program to select appropriate terms.

Intelligent or automated contracts are the term used where the contract seeks to manage themselves. Szabo drew an analogy with a vending machine where the payment has to be received before the fizzy drink is dispensed. This *"money first, goods second"* approach can be disregarded if the technology allows for the seamless, real time exchanging of goods/services for money. The use of big data and censors allows payment to be made instantaneously through crypto- currency. The first known cryptocurrencies developed in the late 1980's (Griffith, 2014) however, the crucial development happened in 2008 when Satoshi Nakamoto published the white paper 'Bitcoin: A Peer-to-Peer Electronic Cash System'.

Nakamoto identified the issues of using a trust based model, relying on financial institutions to process payments, and provided a solution. His electronic payment system removed the need for trust in a third party and introduced a system based on cryptographic proof. He explains how an electronic coin 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.

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 banks. Blockchain has been described as the fourth industrial revolution[iii] (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. 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.

 The cross verification of the process by multiple reference points prevents the abuse of the system and builds the participants confidence in the system.

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).

The ultimate logical extension is for whole projects to be executed from inception to completion with no need for human interaction. This definition is used by lawyers describing the phenomenon *"Contracts that are fully executable without human intervention"* (Morgan, 2014), *"A self-executing contract, containing electronically drafted provisions which have the ability to automate a variety of processes in accordance with the terms of the contract"* (Shedden, 2016). Central to the ability for the contract to be automated is the monitoring. Two commentators observed that what is required is *"self-enforcing, monitoring external inputs from trusted sources in order to settle according to the contracts stipulations"* (Peters & Panayi, 2015). Another view (Caderia, 2015) is that intelligent contracts will secure payments and are an opportunity to protect parties from insolvencies and late payments. An intelligent contract could be comprised of not one but thousands of mini-contracts all self-executing and transferring data as they complete and generating payment once installed and the relevant online documentation such as performance attainment and continual monitoring have taken place.

The adoption of intelligent contracts poses many challenges (Norton Rose Fulbright, 2016). A software program can in theory exist for many years. However, it is difficult to produce coding intended for a long duration where external information sources may cease to exist. The irrevocable nature of the arrangement also poses problems in terms of satisfying both parties that the coding is operating as they intended. Confidentiality and the open nature of distributed ledger technology pose additional challenges as does the pseudonymous nature of these undertakings. Storage constraints, reliability and compatibility issues also require workable solutions before wide-scale adoption of the technology is possible.

A semi-automated approach is preferable given the seriousness of the issues highlighted. Contracts usually require judgment and the use of discretion which requires subtlety and richness in the language which is extremely different to code. The benefits of intelligent contracts are diluted by this dependency on one or other of the parties. Nevertheless, value can still be added by the automation of certain processes.

The appetite and enablers towards a semi-automated position for construction contracts are discussed in this paper. The overlap with existing elements of construction best practice demonstrate the latent potential.

## Methodology

The literature presented establishes the hypothesis that semi-automated intelligent contracts can gain traction in the construction industry. . Data, in this case secondary, is then collected  and presented alongside the discussion element of the paper. Emerging themes are then reviewed before conclusions are drawn and recommendations made. Clearly, primary data can be more rigorously interrogated than a sample of secondary data. A focus group based approach is scheduled for a follow-up to this work. The secondary data was collected from online fora where the identities of the contributors are unknown to the viewer[iv]. Three prominent contributors to the debate were followed and their responses studied. Contributor A and B were chosen due to their sceptical attitude towards intelligent contracts. Contributor C had a much more positive attitude and appeared to work with blockchain technology. Their views and perceptions are introduced during the discussion section. This data is not presented as being necessarily conclusive or as evidence for any conclusions made. The aim is to portray a sense of the underlying attitudes towards information technology generally.

## The Enablers of Intelligent Contracts within the Construction Industry

Intelligent contracts require the following as a minimum in order to function: BIM level 3 and beyond, cryptocurrencies and the blockchain, big data/internet of things and appropriate payment mechanisms and liability arrangements.

### BIM

BIM's establishment appears to be a pre-cursor to intelligent contracts in order to build a platform where the latter can operate. A review of the progress made with BIM is therefore important. The latest pronouncement on the enablers for a digital age of construction have been reviewed recently (Mosey, 2016). The proposition is that BIM enables, and depends upon, more integration and collaboration amongst the project team members. Issues as to the reliability of BIM computer software programs and models have encouraged a defensive contractual approach to legal liability. Intelligent contracts can be seen as an extension of BIM in that once levels 2 (collaborative working), 3 (a single shared project model), 4 (the use of BIM data to analyse time), 5 (costs management) and 6 (facilities management)[v] are complete then automation in the contract can occur.

Standard form contracts have taken a light touch to inclusion of BIM provisions to date. Standard forms of construction contract refer to the Construction Industry Council BIM Protocol (CIC Protocol)[vi]. This umbrella organisation has sought to encourage BIM adoption by providing a contractual "add on" which operates by being executed by the client bilaterally with each project team member including every consultant and main contractor. The network of bilateral agreements is completed by the main contractor signing the agreement with all its subcontractors and suppliers making design contributions. The CIC Protocol takes precedence over the consultant appointment, building contract and sub-contracts in the event of a conflict or discrepancy.

The interconnecting network of bi-lateral contracts is an effective way of creating the necessary "consensus ad idem" if there is not going to be a multi-party contract. There appears to be a general

acceptance of where this is headed. The Joint Contracts Tribunal, producers of the most popular UK contracts, has indicated that they are considering a multi-party approach (Saxon, 2016). The less well used Project Partnering Contract (PC2000) already uses this approach and claim their contract was used to deliver BIM without any amendment. The multi-party nature of the contract was the perfect match for the hub and spoke approach of BIM (Mosey, 2016).

The shortcomings of the current prevailing attitudes towards BIM are evident in the CIC Protocol. The light touch in evident in that there is no warranty as to the integrity of the electronic data exchange (clause 5) and no liability for the modification, amendment, transmission, copying or use of BIM models other than for agreed purposes (clause 7). The most telling limit in the Protocol is the obligation of the project team members it to use "reasonable endeavours" described (Mosey, 2016) as a *"lower, less clear duty of care than the widely accepted standard of reasonable skill and care"* (clause 4.1.2). The compliance with the timetable is also stated to be *"subject to events outside the reasonable control"* described as a generic exception which overrides the detailed provisions for extensions of time contained in most standard form building contracts. This is a less than promising start for a base for intelligent contracts. Such uncertainty obviously meant to allow people to get used to BIM in a way which will not put them or their insurers on edge.

BIM enables design inconsistencies to be revealed through clash detection. The notion here is that issues arising between the different designers' inputs can be resolved in the model before it is built without the ensuing problems which would be encountered in real time. This gives rise to additional work in re-designing and the issue of whether this is treated as a claim needs to be addressed. Perceived threats to intellectual property rights have been seen as a potential obstacle to the adoption of BIM. Ownerships and permissions should be clearly stated and licences granted in respect of contractor and sub-contractor involvement.

BIM level 3 renders the contributors work indistinguishable and does not notify the author of a change. This is where the multi-party future of construction contracts appears unavoidable. Only by having a joint policy of insurance can insurable liability be dealt with. PPC2000 has direct mutual

licences. The BIM Execution Plan is where the role and responsibilities of team members are set out. Making this document, together with the Employer's Information Requirements contract documents appears to be the step forward in concretising BIM in the contractual process.

The promotion and monitoring of BIM is undertaken in the United Kingdom by the National Building Specification (NBS) organisation. Surveys undertaken (NBS, 2015) demonstrate that a single platform is not yet established as the BIM provider given that 26% did not rely on a single piece of software. Any problems experienced with the software and whom this is exposes to liability is a concern. The interoperability of the software is another outstanding issue.

Adoption of a multi-party contract is put forward as a workable solution to the issues around BIM level 3 adoption. If intelligent contracts rely on BIM then further developments need to happen down this route. The counter-argument is that intelligent contracts do not need to align themselves so closely with the BIM agenda and can return instead to a simple transactional basis. This would result in not one multi-party contract but thousands of straightforward contracts executed by performance and self-executing in this sense. This approach could be facilitated by the adoption of cryptocurrencies in the construction context. The interim payment for component parts of a build could use blockchain technology. Each component would be individually chipped and once big data sensors attest to its successful installation and function then the payment will be generated. Human intervention here is not strictly required. The simpler the construction or engineering component being undertaken, and the shorter duration, the better in the first instance. Laying rails or achieving electrification of a line could be relatively simply ascertained.

## Big Data/ Internet of Things

The technology exists to provide the information needed for the blockchain to be gathered by its multiple reference points. The embedding of censors in devices is already in wide usage and is set to pass 25 billion by 2020 (Gartner, 2014). Project managers are able to monitor deliveries of materials by tracking the location information embedded in the goods in transit. Project managers maintain a

dashboard of building performance based on information being sent from installed plant and other products. It appears logical that the censors should report back to the federated BIM model where planned completion is over-written with actual performance on the project.

## Project Bank Accounts

Reference was made in the introduction to the partnering debate which has been in place for the last twenty years. Various legal initiatives were launched to mandate good performance and capture the zeitgeist of collaborative construction. These initiatives continue to be met with a mixture of acceptance and ambivalence. Certain amongst these legal tools are extremely useful in paving the way for intelligent contracts. Foremost are project bank accounts and project insurance. Project bank accounts provide a novel solution to supply chain payment issues. The rationale is that the main contractor and sub-contractor needed to agree on the amount to be withdrawn from the project bank account in satisfaction of the sub-contractor's entitlement. The main contractor would not be able to access their own share of the money until this agreement was forthcoming. Other government initiatives such as the payment of sub-contractors within 30 days have gone some way to address the payment abuse issues experienced.

## Project Insurance and Blame-Free Construction

The construction industry is wedded to the need for accountability and for liability to attach to those who err. The contractual networks are essentially predicated on the notion of attributing the blame to the culpable party. Moving away from a blame culture is encouraged by the use of project insurance. This was seen in the United Kingdom on the Terminal 5 Heathrow building (Potts, 2008). Supply chain problems became issues for the project as a whole and were resolved at a team level. Project insurance involves procuring a single policy of insurance rather than the multiple policies normally encountered on a building project.  Project insurance would provide an environment in which real collaboration and intelligent contracts could flourish.

## The Basic Construction Contract Obligations

The basic obligations discussed below represent the commercial bargain struck between the parties. These are the essential obligations undertaken and the rationale as to why a construction contract is required. The matching obligations are introduced before the replicability of the term in an intelligent contract are considered.

### Pay/build

The contract must say when, where and how the Contractor is being paid and what for. In return, the services rendered by the Contractor must be made clear. Advances in cryptocurrency, big data sensors and project bank accounts can lead, at the very least, to the semi-automation of this function. The issue then centres on verification of the completion of the work to the standard required. At the very least, this function can be made quicker and cheaper by adopting an intelligent contract approach. Spot checking and the harvesting of indicators into a dashboard would represent advancement.

### Instruct/obey

The ability to make decisions for and on behalf of the Employer needs to be included in the contract. The terminology used varies and the office holder may be known as the Architect/Contract Administrator or the Project Manager or Engineer. The extent to which the Contractor is required to obey any direction given needs to be defined. Questions arise around whether the Contractor has a right to challenge any decision made and whether this can be before or after taking the compliant behaviour.

The role of the overseer is required, amongst other things, to record when time and money events have happened. Other roles include dealing with discrepancies between contract documents and issuing variations. The overseer has ancillary powers such as excluding parties from site and ordering the cessation of work in the event of force majeure or the discovery of archaeological remains in the area.

The suitability for automated contracts to deal with change and uncertainty is a major issue preventing the realisation of intelligent contracts. An automated process can deliver the BIM model. Doubt surrounds the ability to code, say, the force majeure clause.

Dealing with uncertainty can be interpreted simply as the requirement to provide a dispute resolution clause. Typically, this refers that in the event of dispute the parties should refer to either mediation, adjudication, arbitration, litigation or a dispute review board. However, prevention is better than cure.

Construction contracts also deal with uncertainty by containing wording allowing a flexible approach to be taken. One of the important clauses and one which does not result from the English law is the force majeure clause. Often there is a list of the type of events giving rise to the possibility of an extension of time and/or extra payment. Discretion is provided for in the wording "or such similar event." This discretion or room for interpretation can be likened to an expansion joint allowing the bridge to move within limits to deal with different pressures and outcomes.

A feature of intelligent contracts is that they will be unable to cope with "wriggle room" type provisions. A computer programme is made up of algorithms which are essentially "if this then this". Can a force majeure clause be reduced to a set of algorithms – can it provide for the unexpected? This, in the long run is likely to be the major obstacle in the adoption of intelligent contracts. This is separate from the challenge of having the clients agree to give irrevocable control to the machine. Commentators on intelligent contracts have talked of the need for a "kill switch" to wrestle back control in the event of an unpalatable outcome[vii]. Other commentators point out that whilst some elements of a construction contract can be automated, such as the PAY BUILD function, there should always be an element of human sanction. This is the semi-automated version of the intelligent contract.

The eventual sophistication of the computer in being able to resolve disputes and confront the unexpected is the logical extension of this approach. Singularity is the term used to describe the day when the robots take on human levels of intelligence and think for themselves[viii].

### Set deadlines/Meet deadlines

Timing is a crucial feature in building contracts and is often equated to having the same importance with money. The building contract must therefore provide a mechanism for setting the original timescale but as importantly must also give a mechanism to move the deadline upon the occurrence of certain events. The processing power of existing computers could accomplish the task of predicting and remodelling a programme to take account of eventualities. Research is currently being undertaken in the University of the West of England to interrogate data based on 5,000 projects to produce an intuitive add-on to existing project management software.

### Give Access/Take Possession

The Contractor cannot be expected to carry out and complete the works unless he is given access and can take possession of the site. Directions as to how and when this will happen and the responsibilities that pass to the Contractor consequent on this need to be spelt out in the contract. This matching set of key obligations appears to provide no great challenge in terms of automated construction. Provided the necessary safeguards and insurances are in place and the necessary permissions and planning restrictions have been satisfied then automation appears possible here.

### Give Design/ Follow or Complete Design

The Contractor must be given some indication of what he is to build. The degree of detail given ranges across the forms of procurements available.  Another variable is the extent to which the Contractor is required to complete the design from the stage at which it is handed over. This procedure is used in design and build procurement. Questions can arise around what happens with ambiguities or errors in design information and the interface between different personnel in the design team. Huge advances in BIM have already been seen with the result that automation in this field is far advanced. Issues still remain including: inadequacies in the leading BIM protocol, intellectual property issues, collective responsibility and insurance arrangements.

A myriad of other issues exist around a building contracts such as insurances, health and safety requirements, sub-contracting, determination provisions and liability for the cost of over-runs. These issues are capable of falling into place once the basic functions are addressed and replaced by automated/intelligent construction features.

## Discussion

Observations on intelligent contracts are made in this section interspaced with indicative views from construction professionals obtained from a secondary data source. Intelligent contracts are deemed desirable because they will save costs and time in automating certain aspects of construction project performance as well as saving costs and time in transaction arrangements. The potential to provide ongoing as-built information for use in whole life costing is also attractive for clients.

Recognising the positive effects achievable through intelligent contracts is not universal. Contributor A to the online forum stated "*decentralisation [seeks]… to replace people as they view as unnecessary middle-men. The absurd autonomous organisation idea is an extension of that concept.*" The same contributor continues*: "Smart contracts are the stupidest misunderstanding of the world the blockchain movement has produced yet."*

Contributor B was not so dismissive of the central notion but succumbed to the temptation with contemplating future technology is to take things to their logical conclusion without question. *"I guess maybe someday we'll have a god like AI….but we're not close and I'm not convinced that it's possible".* Contributor C was more positive and made the comment "*"complexity is not insurmountable."*

The discussion on the forum addressed the point about whether intelligent contracts can deal with the uncertain elements in a construction project and resolve the ensuing disputes. Contributor A: *"Disputes do not revolve around inaccurately recorded information and it is not the case that having a secure ledger to record transaction/contract details would solve most problems."* Contributor B agreed

by making the point: *"genuine disagreements between two reasonable people can't be solved objectively by a computer."*

Respondent C had a different approach stating: *""of course parties can be intractable and a course of action dealing with that condition would be required, but if agreeing upon dispute resolution procedures and third-party consultants as part of the construction contracts is common practice now, why wouldn't similar measures for reducing disagreement be applied in automated contracts? We are teaching computers how to paint, why can't we teach them how to lawyer?"*

The discussion returned to the semi-autonomous advancements possible through intelligent contracts. Contributor A and B recognised that record keeping and payments could be regulated through intelligent contracts although remained dismissive of these benefits: Contributor A *"If all the smart contract can do is move money around when clearly objectively defined conditions are met, then it's just an automated escrow; big deal."* Contributor B *"Ultimately all a computer can do is check some numbers against some other numbers. Human interaction if generally more complicated and nuanced that that."* Again, it fell to Contributor C to recognise the potential here: *"When those numbers are certified to represent identity, authority and agency it is a rather powerful combination."* On the disputes point: *"Avoiding lawsuits and reducing instances of substantial disagreement is an excellent use for immutable distributed record keeping…When facts are harder to dispute, there are less disputes."*

Looking further ahead, Contributor A remained as the voice of portentous things to come: *"You ever see Dr. Strangelove? The Soviets had a "smart contract" that said "if nuked, destroy world". Turned out to be a bad idea."* Contributor A continued: *"There is also one major threat with every custom smart contract: if there's a bug, you're permanently screwed."* Contributor B took a more pragmatic approach to the shortcomings: *"Please tell me where the information a "smart contract" uses to process comes from. Answer: from some arbitrary APIs (Application Program Interface) which may not be accurate, or may not be updated at the right term, or any other thousands of issues – malicious*

*intent, spilt coffee. There's an old software adage that goes "garbage in, garbage out" that is it down's matter how beautiful or well written your code is, if you receive garbage input, you'll invariably have garbage output."*

Contributor C who re-enforces the potential for intelligent contracts. "*Blockchains can increase the authority, security and transparency of recordkeeping systems and smart contracts can enable interoperability with other systems such as payroll, insurance and supply chains. A major cost drier of public projects in accountability oversight. If specifications, bids, RFIs, purchase orders and delivery schedules are automated, validated and transparent on a globally accessible blockchain… that tracking costs as well as the redundant overhead can be reduced and theoretically corruption would have less places to hide.*"

Contributor C focuses instead on the incremental improvements that intelligent contracts can make in terms of project savings. "*A smart contract for escrow can eliminate the need for a third party as a temporary possessor of funds or deeds, reducing risk exposure, service fees. It can accelerate processes from days, weeks and months, down to seconds, minutes and weeks depending on the complexity of preconditions for closing.*"

This vision of incremental improvement represents the best chance of intelligent contract adoption. A system can be put in place between the client and main contractor and replicated between the subcontractors and suppliers. The payment clause is automatically executed through crypto-currency once the works are completed and have satisfied the contract. The extent to which human intervention will be required to physically check is an issue needing resolution if full automation is to become possible.

Taking an example to demonstrate the potential, a weather provision in a typical construction contract provides some valuable insight. A traditional contract lists exceptionally adverse weather as a relevant event, thereby allowing an extension of time. The contract does not however, define what is

exceptionally adverse so in theory this is open to interpretation. However, the New Engineering Contract deals with weather objectively and employs the 1 in 10 year value assessment. This is a term of contract which can be written into code and automated. This can be achieved by linking meteorological office recordings against the criteria in the blockchain.

As has been noted, creating the algorithms for force majeure and the other instances where matters are referred to the discretion of the certifier is more difficult to imagine. This leads to the position, and the desirability, of maintaining some human involvement in the process. BIM and associated revolutions are disruptive but this gives professions the choice of evolving new roles for themselves. Operating semi-autonomous construction contracts would appear just such a challenge.

## Conclusions and Further Research

The idea that there will be intelligent contracts paying for performance upon the sensors signalling compliance is unlikely to be achievable in a vacuum. There is a link with the range of advances required for the collaborative agenda to be re-imagined for the digital age. The advances in BIM, in multi-party contracts, in project insurance can all be seen as pieces of the jigsaw. The discussion has demonstrated the deeply held perceptions and nervousness of key stakeholders towards intelligent contracts. The business case for their adoption must remain the focus whilst technology overcomes the temporary barriers of reliability and interoperability.  Ultimately, addressing these concerns is a waiting game for the technology to reach the stage in its maturity where it works and the public have enough faith in the ability to deliver.

# References

Cardeira, H (2015) 'Smart Contracts and their applications in the construction industry' Available from:http://heldercardeira.com/H%20Cardeira%202015%20-%20Smart%20contracts%20and%20possible%20applications%20to%20the%20construction%20industry.pdf [Accessed 24/09/2016].

Cassano, J (2014) 'What are Smart Contracts? Cryptocurrency's Killer App' Available from: https://www.fastcompany.com/3035723/app-economy/smart-contracts-could-be-cryptocurrencys-killer-app?show_rev_content [Accessed 01/06/216]

Currie, L. (2014) Building Information Modelling: Its impact on design liability, insurance and intellectual property rights, *Society of Construction Law Papers* D169.

Digital Economy Outlook (2015) 'Smart Contract: the ultimate automation of trust?' BBVA Research. Eris Industries. Available from https://www.bbvaresearch.com/wp-content/uploads/2015/10/Digital_Economy_Outlook_Oct15_Cap1.pdf [Accessed 01/06/2016]

Gartner (2013) Gartner Identifies the Top 10 Strategic Technology Trends for 2014 Available from: https://www.gartner.com/newsroom/id/2211115 [Accessed 26/11/2016]

Griffith, K (2014) 'A quick history of cryptocurrencies BBTC – Before Bitcoin' Available from https://bitcoinmagazine.com/articles/quick-history-cryptocurrencies-bbtc-bitcoin-1397682630 [Accessed 02/10/2016]

Higgins, C (2015) 'Is disruptive innovation possible in the construction industry'. Available from http://themidnightlunch.com/disruptive-innovation-construction-industry/ [Accessed 02/10/2016]

Kamat, V.R., et al. (2001), Visualizing simulated construction operations in 3D, Journal of Computing in Civil Engineering, ASCE, 15(4), 329-337.

Kemp, R (2016) 'The Fourth Industrial Revolutions: Blockchain and Smart Contracts' Available from https://www.thelawyer.com/issues/6-june-2016/the-fourth-industrial-revolution-blockchain-and-smart-contracts/ [Accessed 21/09/2016]

Lewis, A (2016) 'A gentle introduction to smart contracts'. Available from https://bitsonblocks.net/2016/02/01/a-gentle-introduction-to-smart-contracts/ [Accessed 01 June 2016]

Mason, J. (2016) *Construction Law from Beginner to Practitioner,* Routledge Publications

Mason, J. (2007) The views and experiences of specialist contractors on partnering in the UK, *Journal of Construction Management and Economics*, 25 (5). pp. 519-527.

Mason, J. (2007) Contracting in good faith – giving the parties what they want *Construction Law Journal*, 23 (6). pp. 436-443.

Mason, J. (2009) Ethics in the construction industry: the prospects for a single professional code *International Journal of Law in the Built Environment*, 1 (3). pp. 194-205.

Morgan, P (2014) 'Pamela Morgan at Bitcoin South: Innovating Legal Systems through Blockchain Technology'. Available from: http://bravenewcoin.com/news/pamela-morgan-at-bitcoin-south-innovating-legal-systems-through-blockchain-technology/ [Accessed 01/06/2016].

Mosey, D., Howard, C. & Bahram, D. (2016) Enabling BIM through procurement and contracts, *Society of Construction Law Papers* D192.

Nakamoto, S. (2008) 'Bitcoin: A Peer-to-Peer Electronic Cash System' Available from https://butcoin.org/nitcoin.pdf [Accessed 24/09/2016]

NBS (2015) National Construction Contracts and Law Survey Available from https://www.the**nbs**.com/.../**nbs**-national-construction-contracts-and-law-**survey**-2015

Norton Rose Fulbright (2016) *Smart Contracts: Coding the Fine Print* https://nortonrosefulbright.com [Accessed 25/10/2016]

Peters, G. & Panayi, E. (2015) 'Understanding Modern Banking Ledgers through Blockchain Technologies: Future of Transaction Processing and Smart Contracts on the Internet of Money'.

Potts, K. (2008) *Construction Cost Management: Learning from Case Studies*, Spon Text.

Robinson, E & Leising, M (2015) 'Blythe Masters Tells Banks the Blockchain Changes Everything' Available from http://www.bloomberg.com/news/features/2015-09-01/blythe-masters-tells-banks-the-blockchain-changes-everything [Accessed 29/09/2016]

Saxon, R. (2016) Building Interview available from http://www.building.co.uk/interview-richard-saxon/5083020.article [Accessed 11/10/2016].

Sheddon, A. (2016) An introduction to Smart Contracts. Available from: https://www.burges-salmon.com/news-and-insight/legal-updates/an-introduction-to-smart-contracts/ [Accessed 21/09/2016].

Szabo, N. (1994) 'Smart Contracts'. Available from: http://szabo.best.vwh.net/smart.contracts.html [Accessed 26/09/2016]

Tyulkanov, A. (2016) '3 Thoughts on 'A Gentle Introduction to Smart Contracts''. Available from: https://bitsonblocks.net/2016/02/01/a-gentle-introduction-to-smart-contracts/ [Accessed 01/06/2016]

Wang, H.J., et al. (2004). "4D dynamic management for construction planning and resource

utilization," Automation in Construction, 13(5), 575-589.

Watanabe, H. et al (2016). 'Blockchain Contract: Securing a Blockchain Applied to Smart Contracts'.

IEEE International Conference on Consumer Electronics. pp.467-468.

---

[i] Government Construction Strategy 2016-2020. Available from:
https://www.gov.uk/**government**/.../**Government_Construction_Strategy_**

[ii] Digital Built Britain Available at: http://www.digital-built-britain.com

[iii] The first three were: (1) mechanisation of the textile industry (2) technological revolution (3) internet technology and renewable energy.
[iv] https://www.reddit.com/r/Buttcoin/comments/4dcoe1/why_are_smart_contractsdaos_a_bad_idea/
[v] https://www.thenbs.com/knowledge/bim-levels-explained
[vi] https://www.**cic**.org.uk/download.php?f=the-**bim**-**protocol**.pdf

[vii] http://www.bbc.co.uk/news/technology-36472140
[viii] Isaac Asimov's Robot Series first appeared in 1954 and is startlingly accurate.