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Technological, organisational and environmental determinants of smart contracts adoption: UK construction sector viewpoint

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ABSTRACT

This study aims to identify the factors that influence the adoption of smart contracts in the UK construction sector. A deductive questionnaire-based approach informed by the technology-organisation-environment (TOE) model is adopted. The framework is comprised of twelve independent variables and one dependent variable of smart contracts use intention. Ten hypotheses are developed to statistically test the causal relationships between the eleven variables of the research model. The study adopts a convenience sampling approach, with the population of interest being primarily drawn from among UK construction practitioners. The results generated from linear regression analysis suggest that the following four factors have a significant influence on the adoption of smart contracts: supply chain pressure, competitive pressure, top management support, and observability. The descriptive statistics obtained also offer a greater understanding of the perceptions and attitudes towards smart contracts across the UK construction sector. The results demonstrate the usefulness of a perception-based model that utilises the TOE framework to assess facets that influence the adoption of smart contracts. The study contributes to innovation diffusion studies in construction project management and supports "early adopters" at the footfall of the technology's diffusion curve.

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Smart contract; use intention; technological; organisational; environmental; the construction industry

Introduction

A smart contract, introduced in the mid-1990s (Szabo 1997), is an automated, fully executable transaction protocol that operates without the need for human intervention. A smart contract is self-reinforcing in that legally binding contractual conditions are coded in the program and are executed only once the coded clauses are met. Transaction information such as payment amounts is embedded in smart contracts, and funds are automatically transferred between the contracting parties once the stipulated instructions are satisfied. The general objectives of smart contract design are to satisfy common contractual conditions (such as payment terms), align expectations, and minimise the need for trusted intermediaries (Mason 2017, Uccuru 2017). The disruptive nature of smart contracts is more evidenced in the banking and financial sector: the European Commission Trend Report (2016) estimated that smart contracts could reduce bank infrastructure costs by as much as EUR 18.4 billion per annum by 2022.

Smart contracts are claimed to disrupt the "traditional" models of contracting in the construction sector (Mik 2017, Savelyev 2017). Moreover, smart contracts can offer significant benefits in the construction sector, particularly in terms of protection against late payments among contracting parties, and such contracts may thus reduce the prevalent contractual disputes, cash flow problems and business insolvencies in the industry (Sambasivan and Soon 2007, Tran and Carmichael 2012). Indeed, studies by Assaf and Al-Hejji (2006) and Kim *et al.* (2009) found that late payments and withheld or refused payments are among the major causes of delay in the delivery of construction projects. Thus, smart contracts are advocated to offer significant time and cost efficiencies. Nevertheless, while the trustworthy payment environment facilitated through smart contracts has substantial advantages, smart contract adoption remains in its embryonic stages in the construction sector.

To comprehend the diffusion of technology among construction organisations, the proponents of smart contracts in the construction industry need to be appraised. As established from the reviewed literature, no existing research study has fully endeavoured to address this issue. Hence, this research study seeks to fill this empirical gap. The main objective of this study

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is to examine the adoption of smart contracts in the UK construction industry. Specifically, the study is underpinned by one main research question: what are the factors that influence managers' decision to adopt smart contracts in the UK construction industry? To answer this question, the research study utilises the technology-organisation-environment (TOE) framework (DePietro *et al*. 1990) and proposes a perception-based model that provides thoughtful adoption intentions and attitudes across the construction sector towards smart contracts. In particular, the proposed framework is intended to aid in the identification of technological, organisational, and environmental facets that influence the adoption of smart contracts in the construction sector.

The article is organised as follows. The next section provides a detailed review of contracting systems in the construction industry and delineates the theoretical foundations of the research by introducing the TOE framework. This overview is followed by an account of the method used to address the research question. The subsequent sections present the findings and conclusions drawn from the primary and secondary data.

Conceptual underpinnings

Procurement and contracts in the construction sector

Procurement refers to the process established by the client to acquire a building or other construction projects (Morledge and Smith 2013). The procurement process can be divided into several stages such as formulating the procurement strategy or approach, the tendering process, the bidding process, subcontractor selection, the type of payment, collaborative tools, and performance evaluation (Eriksson and Westerberg 2011). In terms of procurement strategies, there are several possibilities including traditional approaches such as design-bid-build (DBB); integrated approaches such as design and build (DB); construction management (CM) and management contracting (MC); and collaborative approaches such as public-private partnerships (PPP) (Morledge and Smith 2013). The chosen strategy should follow the overall strategic objectives of the client's business plan (Briscoe *et al*. 2004).

According to Zaghloul and Hartman (2003), construction contracts are "the written agreements signed by the contracting parties (mainly an owner and a contractor), which bind them, defining relationships and obligations" (p. 419). In any given construction project, and to achieve the client's goals, the choice of contract type should ensure the alignment between the client's objectives and the motivations of the contractor through adequate risk allocation (Kozek and Hebberd 1989). There are several types of contract in use in the construction sector, and the most suited contract type depends on the completeness of the information available to bidders at the tender stage and the risk appetite of the client (Gordon 1994, Antoniou and Aretoulis 2018). A study by Zaghloul and Hartman (2003) involving 300 respondents from across the construction industry supply chain found that more than 74% of the contracts employed in construction are prepared contracts written by one of the contracting parties, often the owner, and not negotiated.

Smart contracts in the construction sector

The concept of smart contracts was first promoted by computer scientist Nick Szabo in 1997 (Schneider *et al*. 2018). Szabo defined a smart contract as a "computerised transaction protocol that executes the terms of a contract" (Schneider *et al*. 2018). Smart contracts are fully executable and self-enforcing contracts without the need for human intervention (Mason and Escott 2018).

Smart contracts are enabled by the fast diffusion of blockchain technology (Schneider *et al*. 2018). Blockchain is a digital ledger technology that holds a group of registers and records with a high level of integrity. When the recorded transactions are approved, blockchain applies a global distributed digital network that does not allow changes or alterations. This restriction is safeguarded by using a hash function, which ensures that every block has a unique fingerprint processed and created by a mathematical formula (Kokina *et al*. 2017). Beck *et al*. (2018, p. 1021), have described blockchain as a "decentralised, transactional database technology that facilitates validated, tamper-resistant transactions that are consistent across a large number of network participants called nodes". In simple terms, the fundamental objective of blockchain is to facilitate transparency and trust between anonymous individuals without the use of intermediaries (Surujnath 2017).

As smart contracts are believed to be the future in many different industries, the construction sector may not be immune to the diffusion of this technology (Ashworth and Perera 2018). A smart contract could be used between any two actors in a construction supply chain: between the client and the main contractor, the main contractor and subcontractors, the subcontractors and suppliers, and among other contractual combinations along the chain. A smart contract may be used in payment transactions in the following ways: first, the principal specifies the number of conditions that should be fulfilled for the payment to be issued. At the same time, the payment would be embedded in the contract as digital currencies (i.e. cryptocurrencies). Once the service provider fulfils the scope of work specified in the contract, the payment will be automatically issued. As such, a smart contract will protect the main contractors, subcontractors, and suppliers against late-payments and the insolvency of the principal. Indeed, an inquiry into the construction industry insolvency in Australia has found that late payments and withheld payments are the main cause of business failure in the industry (Collins 2012). Delayed payments were also found to increase project cost, prolong completion time, and adversely affect the quality of the project outcomes (Assaf and Al-Hejji 2006, Gandhak and Sabihuddin 2014).

The construction industry is characterised by highly opportunistic and adversarial relationships between the contracting parties (Boukendour 2007). Disputes among clients, contractors, subcontractors, and other supply chain actors often reach the courts of law and are dealt with through measures such as adjudication, party-to-party negotiation, and arbitration (Fenn *et al*. 1997, Cheung and Yiu 2006). The Arcadis' report "*Global Construction Disputes Report 2020: Collaborating to achieve project excellence*" (Arcadis 2020) have shown that the average value of disputes in the UK construction industry reached $17.8 million in 2019 and took an average of 9.8 months to be resolved. In studies that set out to determine the main causes of disputes in the construction industry, Cheung and Yiu (2006), Cakmak and Cakmak (2014) established that contractual problems are the most common causes of dispute in projects. Payment-related triggering events were found to be at the core of these disputes (Carmichael 2002, Carmichael and Balatbat 2010). Interestingly, attitude towards contractual claims was found to vary across the global construction industry with differences between countries attributed to culture, construction practices, regulations, and the political environment (Chan and Yeong 1995). Nevertheless, the study by Cheung and Yiu (2006) argued for the inevitability of disputes in the industry and recommended that construction professionals adopt a proactive approach to dispute management. The need for a shift from dispute resolution to dispute mitigation is, hence, evident and we posit that smart contracts could form part of such proactive dispute management measures. Indeed, the recent Arcadis report mentioned above (Arcadis 2020), have shown that a staggering 60% of respondents agree that effective contract administration would have the single most significant impact in avoiding disputes in construction. Smart contracts will mitigate against disputes among the contractual parties by reducing conflicts about progress, automating payments, and increasing the transparency of contractual clauses (Mason and Escott 2018). Several studies such as those by Cheung and Pang (2013) and Shen *et al*. (2017) have underlined human factors such as erroneous estimation, deficient documentation, and opportunistic behaviours as major ingredients of construction disputes. Hence, the automated decision-making system embedded in smart contracts may eliminate human interfacing and human misinterpretation of contractual clauses that may lead to disputes. According to Ortolani (2019), the unparalleled contractual automation facilitated by smart contracts may allow for private, self-enforcing arbitration systems to emerge and result in the marginalisation of state courts.

Trust is another important concept in inherently risky contractual transactions (Schoorman *et al*. 2007, Lau and Rowlinson 2009); however, the building of trust is often seen as problematic among supply chain actors working on construction projects (Khalfan *et al*. 2007, Wong *et al*. 2008, Badenfelt 2010). Low trust relationships between clients and contractors were found to increase project costs by 8–20% in risk premiums linked to disclaimer clauses (Zaghloul and Hartman 2003). Smart contacts, being self-executing and self-enforcing, promise to help in the development of trust by shifting the emphasis from "relational trust" to "digital trust" (Shin 2019) based on the confidence in the "rules-of-the-code" (De Filippi and Hassan 2018, Hawlitschek *et al*. 2018). Wang *et al*. (2017) argue that trust in the technology itself will bypass the need for assessments of an exchange partner's honesty, integrity, and truthfulness. A trustworthy network of payments could be established by the contractual terms and conditions being coded in the smart contracts (Kinnaird and Geipel 2017). Payments can then be paid automatically once the stipulated conditions are fulfilled. This trust-building capacity of smart contracts is particularly salient in dealing with the legal and contractual barriers associated with building information modelling (BIM) adoption (Winfield and Rock 2018). According to a report by Winfield and Rock (2018), smart contacts will increase the trust between the contracting parties due to the data records' real-time availability, immutability, security, and transparency.

Smart contracts are espoused to generate greater efficiency by minimising overall costs and reducing waste in the construction industry (Ashworth and Perera 2018). From the reviewed literature, it was found that smart contracts can reduce administrative processes, which would allow billing and checking subsequent calculations of costs to be made simpler, much faster, and more accurately (Kinnaird and Geipel 2017). Smart contracts also eliminate the need for a physical paper-based contract and the associated administrative costs of writing, storing, and archiving such documents (Cohn *et al*. 2017). The digital environment supporting smart contracts may also result in third-party intermediaries such as lawyers and authorities being less critical in governing contractual terms, hence, reducing transaction costs (Mik 2017, Savelyev 2017). In addition to being used to purchase, track and verify goods and services between supply chain actors; smart contracts could be used in transactions involving the ownership transfer of energy, intellectual property rights, and property and land titles (Kinnaird and Geipel 2017).

Notwithstanding the above benefits, smart contract adoption in the construction sector may require fundamental shifts in the contractual relationship between firms. A change in mindset is needed to convince construction firms to switch from their existing procurement models of traditional paper-based contracts to a conventional blockchain-enabled smart model (Mason 2017). The complexity of smart contracts is also heightened by the need for exceptionally accurate coding from the outset, given that the contract will forever reside in the public ledger (Frantz and Nowostawski 2016). Moreover, construction projects are complex undertakings, and many common events such as on-site accidents, new regulations, and force majeure may prove difficult to capture in computer codes (Thompson Reuters 2018). Smart contracts also come with challenges such as limitations over storage capacity, interoperability, data reliability, and confidentiality (Li *et al*. 2019).

Given the abovementioned benefits and challenges of smart contracts in the construction sector, their adoption remains in its infancy phase, and it is widely believed that a long road remains ahead to convince the different parties involved about the benefits afforded by a smart contract (e.g., Cardeira 2015). Hence, this research aims to provide insights into the factors that influence the smart contract adoption intentions of construction industry supply chain actors. The theoretical perspective from which the study is conducted is provided in the subsequent sections.

Technology-organisation-environment (TOE) framework

Several theories have been developed to examine the concept of innovation adoption such as the technology acceptance model (TAM*)* *(*Davis 1989*)*, the theory of planning behaviour (TPB) (Ajzen 1991), the unified theory of acceptance and use of technology (UTAUT) (Venkatesh *et al*. 2003), the diffusion of innovation (DOI) theory (Rogers 2003) and the technology-organisation-environment framework (TOE) (DePietro *et al*. 1990). While the TAM, TPB, and UTAUT explore adoption at the individual level of analysis, DOI and the TOE framework are focussed on the level of the organisation as a decision-making unit. Since this study aims at examining adoption at the organisational level, the TOE framework is chosen as the main theoretical lens.

The TOE framework was first introduced by DePietro and colleagues in 1990 (DePietro *et al*. 1990). This framework explicates the main variables influencing the adoption of technological innovations at the organisational level by looking at three components: technological factors, organisational factors, and environmental factors (Fu and Su 2014). A large number of studies have used the TOE framework to evaluate technological innovations adoption within firms (Oliveira and Martins 2010, Chandra and Kumar 2018). For instance, it has been utilised to examine the adoption of electronic data interchanges (Kuan and Chau 2001), information systems implementation (Thong 1999), e-business (Zhu *et al*. 2004), cloud computing (Gutierrez *et al*. 2015), e-commerce (Hong and Zhu 2006), e-procurement (Teoa *et al*. 2009) and enterprise resource planning (Pan and Jang 2008). In construction industry research, several studies have utilised the TOE framework in the study of e-procurement (Tran *et al*. 2014, Ibem *et al*. 2016) BIM implementation (Ahuja *et al*. 2016, Chen *et al*. 2019) and in the assessment of project complexity (Bosch-Rekveldt *et al*. 2011, Peñaloza *et al*. 2020). The aforementioned studies demonstrate the valuable insights offered by the TOE framework into understanding the adoption of technological innovations across a variety of contexts and industries. The decision to adopt the TOE approach in this research study is driven by its coherence and consistency with other frameworks such as the DOI theory (Ramdani *et al*. 2013, Sila 2013). Hence, following the TOE framework, we propose a perception-based model that postulates that the degree at which a construction organisation decides to adopt and implement a smart contract is influenced by three main groups of determinants: technological, organisational and environmental factors (Soto Acosta *et al*. 2016). These three groups of factors are examined thoroughly below and then linked to the construction industry context to build the conceptual framework for this study.

Technological characteristics

The technological context of the TOE framework is concerned with both internal and external technologies that are relevant to the firm (Gutierrez *et al*. 2015). This includes technologies that exist in the marketplace as well as technologies that are being utilised within the firm (Zhu *et al*. 2004, Gutierrez *et al*. 2015). The technological factors that influence adoption decisions originate from Rogers's (2003) DOI theory and include relative advantage, compatibility, complexity, trialability, and observability.

The first technological factor, relative advantage, is defined by Rogers (2003, p. 229) as "the degree to which an innovation is perceived as being better than the idea it supersedes". What defines this relative advantage is contingent on the specific characteristics of the innovation (Rogers 2003) and is widely seen as a fundamental indicator for the adoption of innovations (Gutierrez *et al*. 2015). In Lee's (2004) empirical study on technology adoption behaviour, the relative advantage was found to be a significant indicator with the probability of an innovation being adopted significantly increasing as a result of its perceived relative advantage. Within the context of the construction domain, a study by Mason and Escott (2018) examining the perceptions of the key stakeholders of smart contracts in the UK construction sector has highlighted several potential advantages to their adoption. Among the possible benefits are the automation of contract formation, the automation of updates and payments, and securing payment to contracted parties. Another major advantage is minimising the occurrence of disputes (Mason and Escott 2018), as smart contracts may provide a sense of security and trust among participants in the project because all rights are protected through the embedded automated payment mechanisms (Cardeira 2015). Based on these considerations, the following hypothesis is proposed:

> **H1:** Perceived relative advantage is positively related to smart contract adoption intention.

Compatibility is the second technological factor. It is defined by Rogers (2003, p. 240) as "the degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters". Given that adopting new advances has the potential to bring substantial changes to the organisation and its practices, its adoption of novel solutions is often met with resistance by organisational members (Ramdani *et al*. 2013). Consequently, the new changes brought by the adoption must be compatible with the existing infrastructure of the organisation (Ramdani *et al*. 2013). Gutierrez *et al*. (2015) affirmed that the probability of an organisation to adopt an innovation is higher if the technology is perceived to be compatible with the organisation's currently existing systems and its values and beliefs. In the case of a smart contract in the construction sector, compatibility is likely to influence its adoption intention by construction practitioners. Accordingly, a smart contract needs to be compatible with the existing contract management systems in the organisation as well as its contract management needs. Compatibility with the organisation's existing values and beliefs is also required. Thus, we postulate the following hypothesis:

> **H2:** Perceived compatibility is positively related to smart contract adoption intention.

Complexity is the third technological factor. It is defined by Rogers (2003 p. 257) as "the degree to which an innovation is perceived as relatively difficult to understand and use". Uncertainty is often associated with complex technologies and can hinder their successful implementation. Indeed, adoption is more likely to succeed for less complex innovations (Sila 2013). Within the context of the construction sector, Mason and Escott (2018) underlined the non-complexity of smart contracts from a user's point of view. Given the characteristics of the pre-coded smart contract, Mason and Escott (2018) suggest that understanding how the technology works or the particulars of the coding process is not a necessity for contract users. Organisations can use and trust the technology without concerning themselves with the complex technical details. The day-to-day users of smart contracts are not required to understand the coding structure and the algorithms behind the technology. Hence, we hypothesise the following:

> **H3:** Perceived non-complexity is positively related to smart contract adoption intention.

The fourth technological factor is trialability, which is defined as "the degree to which an innovation may be experimented with on a limited basis" (Rogers 2003, p. 258). As specified by Lin and Chen (2012), when individuals and organisations are provided with the opportunity to trial an innovation before its actual adoption, the likelihood of successful adoption increases. A study by Ramdani *et al*. (2013) found that trialability is an important factor that influences the adoption of enterprise applications by small and medium-sized enterprises. In their study of e-commerce adoption, Kendall *et al*. (2001) also found trialability to be a significant factor influencing the adoption of technologies. Considering the construction sector, Mason and Escott (2018) highlighted the need for a trial period of testing before the actual implementation of smart contracts. As construction organisations move from the traditional form of contracts to smart contracts, these new contractual systems and technologies will need to be tested to support the development of user confidence and trust in such technologies. Trials will help to avoid failure and glitches (Mason and Escott 2018). Since other researchers such as Kendall *et al*. (2001) and Ramdani *et al.* (2013) have shown that trialability is relevant to technological innovation adoption, it is evident that trialability is equally likely to influence smart contract adoption in construction. Therefore, our fourth hypothesis is formulated as follows:

> **H4:** Perceived trialability is positively related to smart contract adoption intention.

Observability is the fifth technological factor. It is defined by Rogers (2003, p. 258) as "the degree to which the results of an innovation are visible to others". It is generally believed that organisations will be more inclined to adopt new technology if they can observe the benefits that other organisations are reaping from adopting that particular technology. Lin and Chen (2012) study of the adoption of cloud computing stated that observability is a prerequisite for the promotion of new technologies. The researchers point out the need to provide organisations with models of successful business cases of cloud adoption. In the case of a smart contract in construction, observability could be facilitated by generating good publicity about the positive effects of such contracts, while information regarding successful use cases could be made widely available to enable a clear understanding of the advantages of smart contracts as opposed to traditional contracting systems. Based on the above assertions, the following hypothesis is assumed:

> **H5:** Perceived observability is positively related to smart contract adoption intention.

Organisational characteristics

The organisational context is concerned with the characteristics of the organisation itself, such as size and scope (Zhu *et al*. 2004, Oliveira and Martins 2010). In this study, the organisational context includes two main characteristics: top management support and organisational information technology (IT) readiness (Sila 2013). Top management support is seen to reduce the salience of the forces working against the change and help overcome internal resistance. The support of top management can also influence the adoption process by stimulating change through communicating and reinforcing the values and vision of the firm (Ramdani *et al*. 2013). In Chandra and Kumar (2018) empirical study of augmented reality adoption in e-commerce, the authors underlined the importance of top management support in developing a positive perception towards innovation adoption and in providing the needed resources and monitory support. Thus, the following hypothesis is formulated:

> **H6:** Perceived top management support is positively related to smart contract adoption intention.

The second factor is organisational readiness, defined by Ramdani *et al*. (2013, p. 738) as "the availability of the needed organisational resources for adoption". The concept of readiness is concerned with the availability of the necessary skills, IT systems, and resources required to adopt the new technology (Ramdani *et al*. 2013). When the organisation has the needed technological infrastructure, this infrastructure provides the platform required to build further technologies (Oliveira and Martins 2010). Furthermore, the IT knowledge of employees facilitates the development of new applications. Therefore, when an organisation has both the needed infrastructure and IT skills, new technologies can be more effectively integrated and adopted (Oliveira and Martins 2010). Therefore, the following hypothesis is proposed:

> **H7:** Perceived IT readiness is positively related to smart contract adoption intention.

Environmental characteristics

Zhu *et al*. (2004, p. 20) defined the environmental context as "the arena in which a firm conducts its business—its industry, competitors, access to resources supplied by others, and dealings with government". A major environmental factor highlighted by several studies is competitive pressure (Soto Acosta *et al*. 2016). The number of organisations utilising new technology in a particular sector was found to largely impact innovation diffusion, as firms compete to be the pioneers of the latest innovations to secure their competitive advantage. Once there is such competition, the need to adopt new technology is intensified in the business environment (Chandra and Kumar 2018). This fierce competition requires organisations to adopt new technologies to increase quality, reduce cost, and improve their efficiency and effectiveness (Chandra and Kumar 2018). In their study of 2459 firms across the European Union, Oliveira and Martins (2010) found competitive pressure to be a key facilitator for e-business adoption in the telecommunications and tourism industries. They referred to competitive pressure as one of the most important drivers of e-business adoption. Hence, the following hypothesis is devised:

H8: Perceived competitive pressure is positively related to smart contract adoption intention.

Another environmental factor that is known to encourage the adoption of new technology is *supply chain partners' pressure*. Indeed, the behaviour of organisations largely depends on the demands of their customers and suppliers. According to Sila (2013), the pressure from partners can be in the form of force, threats, persuasion, or invitations. As a result, supply chain pressure is identified as a factor that influences the decision of adoption. Accordingly, many studies have highlighted the important role of partners in the successful implementation of technological advances (Powell *et al*. 1996, Soosay *et al*. 2008, García-Moreno *et al*. 2016). Thus, the following hypothesis is posited:

H9: Perceived supply chain partners' pressure is positively related to smart contract adoption intention.

The third environmental factor pertinent to this study is the government support in the form of incentives, subsidies, and regulations, which is known to be an important factor in individual firms' technology adoption decisions (Gibbs and Kraemer 2004). Gibbs and Kraemer (2004) emphasised that in newly industrialising countries such as Singapore, as well as in developing countries such as India, the role of such government support is far more significant than in developed countries such as France and Germany. Government regulations and support can work to either encourage or discourage organisations from adopting new technologies (Chong and Olesen 2017). In a study examining e-business adoption across 113 firms, Al-Zoubi (2013) found government support to be among the most important factors associated with e-business adoption. The following is, thus, hypothesised:

H10: Perceived government regulatory support is positively related to smart contract adoption intention.

In summary, the TOE framework is applied in this study to develop a perception-based model that ascertains the variables influencing the use intention of smart contracts in the construction sector, as shown in Figure 1. The framework comprises of twelve independent variables and one dependent variable of smart contracts use intention. Ten hypotheses are developed to statistically test the causal relationships between the eleven variables of the research model. The next section provides further details on the method and research approach adopted to achieve the study objectives.

Method

A research methodology defines the principles and procedures followed to execute a particular scholarly inquiry, beginning from the researchers' ontological and epistemological positions and extending to the finer details of how data will be collected and analysed. In this study, as illustrated in Figure 2, we assume a positivist ontological stance in which reality is seen as objective and independent from the observer. In turn, the study is epistemologically deductive in that the factors influencing the adoption intention of smart contracts in construction are identified and the relationship between them established by reviewing existing theories and developing a set of hypotheses. These hypotheses are subsequently tested through empirical data collection and analysis to be approved or rejected (Saunders *et al*. 2016). In particular, the independent and dependent variables forming the developed hypotheses are measured numerically and the relationship between them examined through quantitative methods including a questionnaire and a subsequently performed statistical data analysis, as rationalised below.

Sampling and data collection

The study adopted a convenience sampling approach with the population of interest being the UK construction practitioners. A survey was designed and administered through an online survey website (surveymonkey.com). The survey questionnaire elicited participants from the UK construction sector, and this process was managed through a pre-qualification question at the beginning of the questionnaire that ensured that only respondents who met this criterion were allowed to proceed with the questionnaire response. Invitations to participate in the study were distributed through posts on an online networking site (www.linkedin.com), an online construction professional group (Co-operative Network for Building Researchers [CNBR]), and an academic portal (www.researchgate.com). Data collection took place over

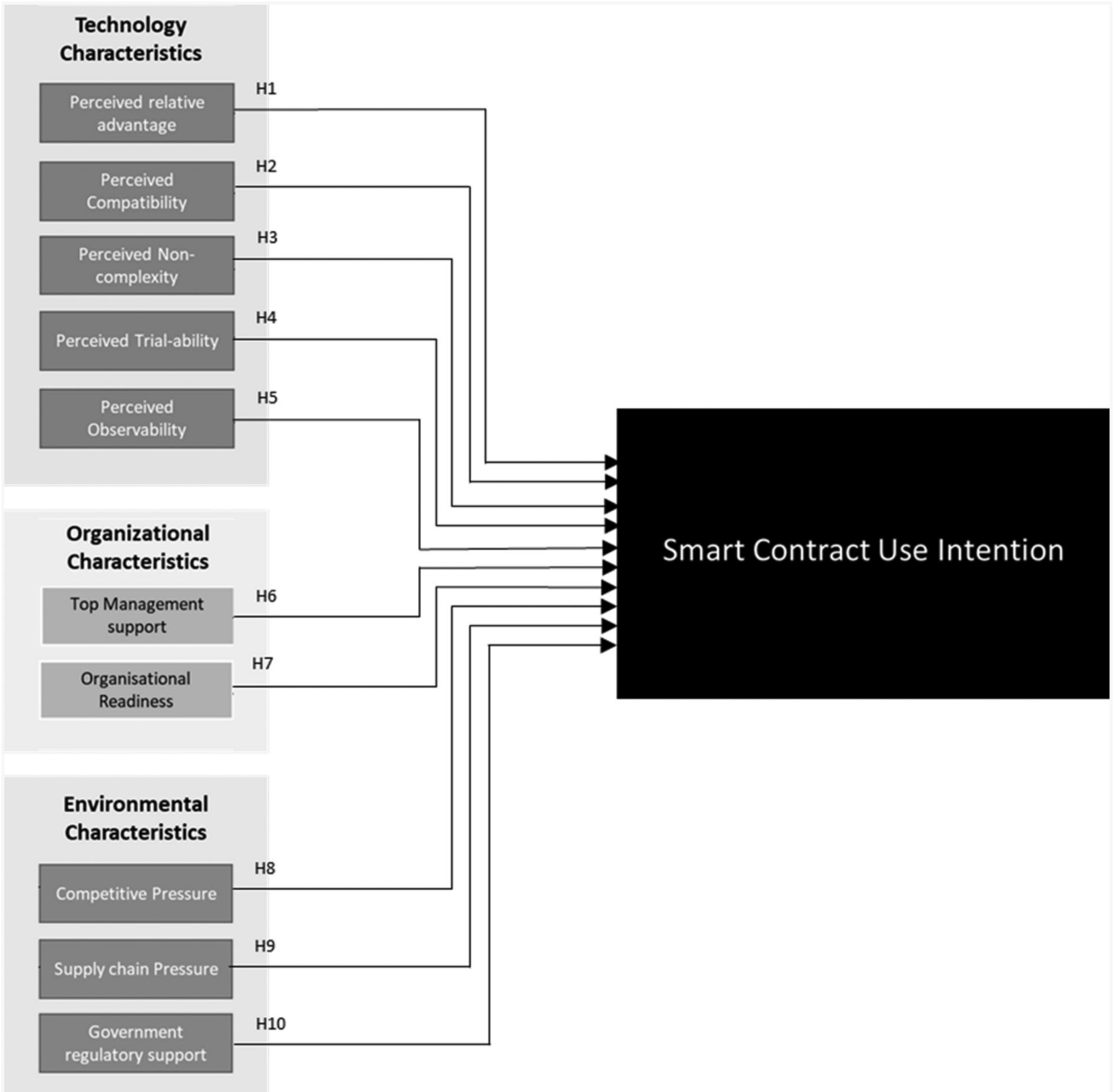

Figure 1. A perception-based model for smart contract adoption.

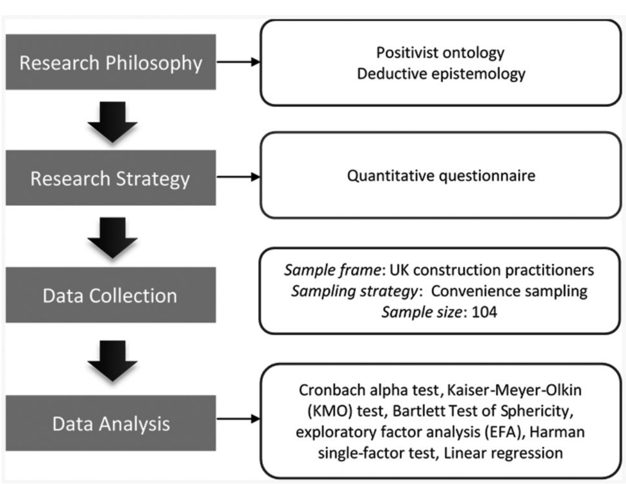

Figure 2. Methodology flowchart.

three months from August 2019 to November 2019. The final database comprised 146 questionnaire responses, of which 42 were incomplete, leaving a total of 104 usable responses (i.e., fully completed questionnaires). The sample was fairly evenly distributed across organisation type, size, age, education, and years of experience (i.e., the total number of years working in the industry), as illustrated in Table 1.

Measures

A set of operational measurement items were used to measure the independent and dependent variables.

Table 1. Participants' demographics.

Characteristics	Respondents (number)	Respondents (percentage of total) (%)
Organisation's Type:		
Client/Owner/Developer	8	7.7
Architecture/Design Consultant	14	13.16
Mangt Consultant/Project Manager	11	10.57
Engineering Consultant	5	4.8
Quantity surveying	7	6.7
Legal Consultant	8	7.7
Main Contractor	22	21.15
Subcontractor	5	4.8
Supplier	1	0.96
Manufacturer	1	0.96
Facility Manager	2	1.92
Academic Institution	6	5.77
Government	14	13.46
Size:		
1–49	24	23.1
50–999	37	35.58
1000–4999	15	14.42
More than 5000	28	26.92
Participants' Years Of Experience:		
0–2	7	6.73
3–5	19	18.27
6–10	32	30.77
11–19	22	21.15
20 +	24	23.01
Participants' Education:		
High School or Less	2	1.92
College Degree	29	27.88
BA/Higher Diploma	57	54.80
Masters	16	15.38
Participants' Age:		
Less than 24	3	2.88
25–30	31	29.80
31–40	38	36.53
41–50	23	22.11
51 or above	9	8.65

To increase the accuracy, consistency, and confidence of measurements, a multiple-item approach was adopted based on perceptual statements, all of which were assessed using five-point Likert scales ranging from 1 = Strongly Disagree to 5 = Strongly Agree. Previously validated scales in the literature were utilised to develop all items, with adjustments made as required to ensure fit with the context of the study. Table 2 below lists the main constructs and their measurement items.

Data was also collected concerning the respondents' firm type and firm size, along with demographic information such as the respondents' age, education level, and tenure.

Validity and reliability

Several procedures were followed to assess the quality of the instrument in terms of its validity and reliability. First, as mentioned above, the adopted operational measurement items were borrowed from the previously published and validated scholarly work (*see* Table 1). Second, a pilot testing of the questionnaire was performed to assess its content validity in terms of the employed measurement items and scales. This pilot evaluation was conducted by sending the questionnaire to three construction practitioners who are experts in the field. The three practitioners were requested to fill the questionnaire, noting the time it took to complete the form and any issues they encountered in terms of their understanding of the questionnaire items, how they navigated the online platform, and the general ease and pleasantness of the experience. Several changes were made following the experts' feedback, particularly in terms of the layout, the font sizes, and the sequence of questionnaire items. Third, measures were taken to ensure the validity and reliability of the constructs through statistical testing using IBM SPSS Statistics v.23 software. Validity indicates the accuracy of the survey questions in measuring what is intended to be measured, namely the study constructs and variables (Cooper and Schindler 2011). On the other hand, construct reliability refers to the consistent interpretation of the survey questions and is defined as the correlation of participants' answers to each question in the survey with their answers to other questions within the same survey (Saunders *et al*. 2016). To examine the constructs' reliability, Cronbach's alpha test was adopted. The results of this testing are illustrated in Table 3. Based on Mallery and George (2003) scale for evaluating Cronbach's alpha results, the construct reliability tests were found to be ranging between "acceptable" and "excellent". One construct, namely PO3, "I have a clear understanding of the positive effects of a smart contract", was found to have a reliability of (.582). This result was deemed unsatisfactory, and PO3 was therefore deleted from the scale to enhance the construct reliability, thereby generating an "acceptable" result of .684.

To further investigate the variables' reliability, two additional tests were conducted: the Kaiser-Meyer-Olkin (KMO) test that measures the sampling adequacy of the data by examining the correlations between individual variables, and the Bartlett Test of Sphericity that examines the occurrence of correlations. The results of these two tests are summarised in Table 4.

Based on the above results, the KMO value is higher than 0.50 and closer to 1, indicating reliable scales (Kaiser 1974). In terms of the Bartlett Test of Sphericity, the results were (.000), which are highly significant and equally indicate reliable scales (Hair *et al*. 2010). To further validate the quantitative data, exploratory factor analysis (EFA) was conducted.

Table 2. Constructs and measurement items.

Construct	Measurement items	Source
PART 1: Technology Characteristics		
Perceived relative advantage		
PRA1	A smart contract reduces payout time.	Ilin *et al.* (2017), Mason and Escott (2018)
PRA2	A smart contract reduces transaction cost.	
PRA3	A smart contract provides secured payments.	
PRA4	A smart contract protects contracting parties from insolvencies and late payments.	
PRA5	A smart contract reduces the occurrence of disputes among contracting parties.	
PRA6	A smart contract increases trust among contracting parties.	
Perceived compatibility		
PC1	A smart contract is compatible with the existing contract management systems in my organisation.	Gutierrez *et al.* (2015)
PC2	A smart contract is compatible with the contract management needs of my organisation.	
PC3	A smart contract is consistent with the existing values and believes of my organisation.	
Perceived non-complexity		
PNC1	A smart contract is easy to understand.	Gutierrez *et al.* (2015), Mason and Escott (2018)
PNC2	A smart contract is easy to use and is manageable.	
PNC3	A smart contract is easy to integrate with existing contractual processes in my organisation.	
Perceived trialability		
PT1	I intend to try out a smart contract in a limited scope in my works, before deciding whether to adopt it in practice.	Ilin *et al.* (2017)
PT2	A trial period before adopting a smart contract in practice will reduce my perceived risks.	
PT3	Being able to try out a smart contract is important in my decision to adopt it in the future.	
Perceived observability		
PO1	There is good publicity about the positive effects of smart contracts.	Ilin *et al.* (2017)
PO2	Other organisations using smart contracts liked using them.	
PO3	I have a clear understanding of the positive effects of a smart contract.	
PART 2: Organisation characteristics		
Perceived top management support		
PTMS1	Top management in my organisation is aware of the benefits that smart contracts can provide.	Gutierrez *et al.* (2015), Ilin *et al.* (2017)
PTMS2	Top management influences employees to increase awareness of the importance/ advantages that smart contracts can bring.	
PTMS3	Top management provides adequate resources for employees to adopt smart contracts.	
Perceived organisational readiness		
POR1	My organisation has the needed resources to support smart contract adoption.	Gutierrez *et al.* (2015), Ilin *et al.* (2017)
POR2	Existing technologies in my organisation support smart contract adoption.	
POR3	Information Technology (IT) staff within my organisation have the adequate skills and experience to support smart contract adoption.	
PART 3: Environment characteristics		
Perceived competitive pressure		
PCP1	The use of smart contracts would offer my organisation a stronger competitive advantage.	Ilin *et al.* (2017)
PCP2	The use of smart contracts would increase the ability of my organisation to outperform the competition.	
PCP3	The use of smart contracts will allow the generation of higher profits to my organisation.	
PCP4	My organisation have experienced competitive pressure to adopt smart contracts.	
PCP5	My organisation would have experienced a competitive disadvantage if smart contracts had not been adopted.	
Perceived government support		
PGS1	Government legislation supports the adoption of smart contracts.	Ilin *et al.* (2017)
PGS2	Legislation about smart contracts is transparent.	
PGS3	Firms are legally protected through smart contacts.	
Perceived supply chain pressure		
PSCP1	My organisation's business partners recommend the adoption of smart contracts.	Gutierrez *et al.* (2015), Ilin *et al.* (2017)
PSCP2	My organisation's business partners have requested the adoption of smart contracts.	
PSCP3	My organisation have experienced pressure from business partners to adopt smart contracts.	
PART 4: Smart contracts use intention		
Use Intention		
UI1	My organisation intends to use smart contracts actively.	Kim *et al.* (2016)
UI2	My organisation intends to actively recommend smart contracts to others.	
U13	My organisation intends to use smart contracts continuously in various projects.	

*Respondents were asked to rate the extent to which they agree or disagree with the statements. All responses were measured on a 5 point Likert scale in which 1 = Strongly Disagree, 2 = Disagree, 3 = Neither agree or disagree, 4 = Agree and 5 = Strongly Agree.

Table 3. Cronbach's α score for each factor of the technology-organisation-environment (TOE) framework.

The variables	Number of items	Cronbach's alpha
Perceived relative advantage (PRA)	6	.849
Perceived compatibility (PC)	3	.741
Perceived non-complexity (PNC)	3	.786
Perceived trialability (PT)	3	.791
Perceived observability (PO)	3	.684
Perceived top management Support (PTMS)	3	.860
Perceived organisational readiness (POR)	3	.770
Perceived competitive pressure (PCP)	5	.834
Perceived government support (PGS)	3	.853
Perceived supply chain pressure (PSCP)	3	.923
Smart contracts use intention (UI)	3	.918

Table 4. Kaiser-Meyer-Olkin (KMO) test and Bartlett Test of Sphericity.

The variables	Kaiser-Meyer-Olkin (KMO)	Bartlett's Test of Sphericity
Perceived relative advantage (PRA)	.786	.000
Perceived compatibility (PC)	.671	.000
Perceived non-complexity (PNC)	.653	.000
Perceived trialability (PT)	.677	.000
Perceived observability (PO)	.500	.000
Perceived Top management support (PTMS)	.721	.000
Perceived organisational readiness (POR)	.643	.000
Perceived competitive pressure (PCP)	.761	.000
Perceived government support (PGS)	.709	.000
Perceived supply chain pressure (PSCP)	.748	.000
Smart contracts use intention (UI)	.751	.000

Principal components analysis with the varimax rotation method was utilised in extracting the constructs. The results of the EFA tests for all constructs were acceptable and proper since each variable result demonstrated that there is only one factor that has an Eigenvalue of more than (1) that explains the collected data for this variable. Finally, testing for common method bias was also performed using the Harman single-factor test. The results indicated that a single factor explains only 32.819% of data variance, which is less than the 50% acceptable threshold advised by Podsakoff and Organ (1986) and indicates no common bias in the data used in the study. Based on the tests above, the data was deemed valid and reliable to perform the regression analysis, as will be explained in the results section that follows.

Linear regression analysis

The IBM SPSS Statistics v.23 program was used to analyse the collected data and verify the study hypotheses. Linear regression analysis was used to identify the significance level of the relation between the predictors' variables and the smart contracts use intention. The purpose of using this analysis technique was to determine which factors have a significant relation with using smart contracts in the UK construction sector.

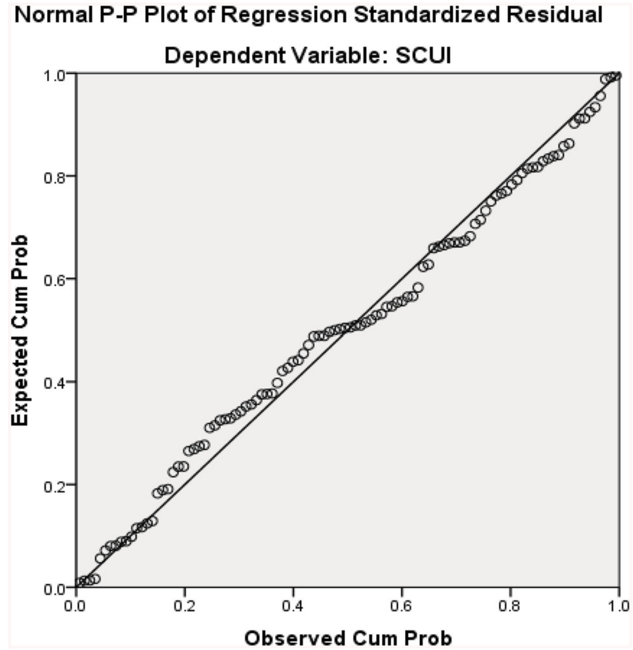

Figure 3. Plot regression.

Table 5. Regression model ANOVA.

ANOVA[a]

Model	Sum of squares	df	Mean square	F	Sig.
1					
Regression	51.300	10	5.130	9.228	.000[b]
Residual	51.700	93	.556		
Total	103.000	103			

[a]Dependent Variable: SCUI.
[b]Predictors: (Constant), PO, PTA, OR, GP, PRA, TMS, PNC, SCP, PC, CP.

The normality assumption was tested for all the variables and was met, along with the normal plot of the residuals, as illustrated in the diagram in Figure 3 below. The normal plot of the residuals shows the points close to a diagonal line; thus, the residual normality is equally satisfied, and no obvious outlier can be identified. Hence, regression analysis can be run for the model. The results of the regression analysis are shown in Tables 5 and 6. Table 5 demonstrates that the dependent variable smart contract use intention is significantly predicted by the independent variables listed. Table 6 shows the estimated coefficients and statistics for each of the predictors that were included in the model, as well as the collinearity test results.

Based on the above results, no apparent multicollinearity problems were found in the model, since none of the predictor variables has a variance inflation factor (VIF) greater than 10. In other words, there is no variable in the model that is measuring the same relationship as is measured by another variable or group of variables. Most importantly, the results indicate two significant

Table 6. Regression model coefficients.

Coefficients

Model	Unstandardised coefficients B	Unstandardised coefficients Std. Error	Standardised Coefficients Beta	t	Sig.	Collinearity statistics Tolerance	Collinearity statistics VIF
1							
(Constant)	−1.905E-16	.073		.000	1.000		
PRA	−.106	.106	−.106	−1.001	.320	.480	2.085
PC	.153	.106	.153	1.441	.153	.477	2.098
PNC	.040	.102	.040	.390	.697	.522	1.916
PT	.052	.089	.052	.586	.559	.679	1.473
PTMS	.212	.097	.212	2.186	.031	.575	1.739
POR	.085	.089	.085	.949	.345	.677	1.477
PCP	.217	.118	.217	1.842	.069	.388	2.574
PGS	.079	.098	.079	.812	.419	.568	1.761
PSCP	.332	.112	.332	2.968	.004	.431	2.318
PO	−.184	.100	−.184	−1.852	.067	.545	1.834

aDependent Variable: SCUI.

relations at a 95% confidence level between Top Management Support and Supply Chain Pressure with Smart Contract Use Intention. Moreover, another two significant relations at a 90% confidence level are underlined between Perceived Observability and Perceived Competitive Pressure with Smart Contract Use Intention. Hence, it can be concluded that supporting evidence was found to accept the hypotheses H5, H6, H8, and H9. As shown in Table 6, of the four significant predictors of smart contracts use intention, the highest contribution is from Supply Chain Pressure with a positive value of (.332), followed by Perceived Competitive Pressure with a positive value of (.217) and Top Management Support with a positive value of (.212), whereas only Perceived Observability has a negative value of (-.184) in relation to the organisation's likelihood of using smart contracts.

As Table 6 indicates, there was no identified significant relationship between Smart Contract Use Intention and the other six variables including Relative Advantage, Compatibility, Complexity, Trialability, Organisational Readiness, and Government Support. Hence, it is fair to state that hypotheses H1, H2, H3, H4, H7, and H10 are not supported. The factors listed were found not to drive the adoption decision of smart contracts in this study. Possible explanations for this outcome will be explored further in the discussion section below.

Descriptive statistics

Table 7 shows the frequencies of respondents' answers to the questionnaire variables. The findings in the table are expanded upon and linked to the regression analysis findings in the discussion section that follows.

Discussion

This study was intended to identify significant factors that influence the adoption of smart contracts in the UK construction sector. From the linear regression analysis, environmental factors are found to be the most significant determinants, as both supply chain pressure and competitive pressure are underlined as the most significant determinant for smart contract adoption. The first determinant for smart contract adoption intention is found to be supply chain pressure. This finding is consistent with studies that underline the important role of supply chain partners in the successful implementation of technological innovation (Powell *et al*. 1996, Soosay *et al*. 2008, Laforet 2011, García-Moreno *et al*. 2016). Construction organisations may exert conformance pressure on each other to follow suit and adopt new technologies. Indeed, as a smart contract is fundamentally a transactional technology between supply chain actors, supply chain pressure is fittingly a key determinant. This finding also implies that as more supply chain actors adopt smart contracts, greater conformity forces will be applied to other supply chain actors to act similarly. Adopting a supply chain perspective on smart contracts diffusion is warranted, and the applicability of smart contracts in supply chain management has been observed across a wide range of sectors including food (Hackett 2016), pharmaceuticals (Bocek *et al*. 2017) and mining (Rizzo 2016), to name a few. Smart contracts can add value in supply chains by managing the structural and relational complexity among supply chain actors through facilitating increased transparency, traceability, efficiency, and trust among such supply chain actors (Law 2017).

The second determinant is found to be competitive pressure. This finding is aligned with previous studies that underlined competitive pressure as a key

Table 7. Descriptive statistics.

Item Number	Item Questions	Participants' Answers Percentage				
		Strongly Disagree (%)	Disagree (%)	Neither Agree nor Disagree (%)	Agree (%)	Strongly Agree (%)
PRA1	A smart contract reduces payout time.	4.80	1.90	12.50	50	30.80
PRA2	A smart contract reduces transaction cost.	3.80	12.50	13.50	50	20.20
PRA3	A smart contract provides secured payments.	1.90	6.70	26	46.20	19.20
PRA4	A smart contract protects contracting parties from insolvencies and late payments.	3.80	14.40	31.70	40.40	9.60
PRA5	A smart contract reduces the occurrence of disputes among contracting parties.	3.80	10.60	26	39.40	20.20
PRA6	A smart contract increases trust among contracting parties.	2.90	10.60	27.90	42.30	16.30
PC1	A smart contract is compatible with the existing contract management systems in my organisation.	6.70	29.80	30.80	27.90	4.80
PC2	A smart contract is compatible with the contract management needs of my organisation.	3.80	12.50	25	49	9.60
PC3	A smart contract is consistent with the existing values and believes of my organisation.	2.90	12.50	26.90	46.20	11.50
PNC1	A smart contract is easy to understand.	3.80	12.50	32.70	42.30	8.70
PNC2	A smart contract is easy to use and is manageable.	2.90	11.50	26	48.10	11.50
PNC3	A smart contract is easy to integrate with existing contractual processes in my organisation.	5.80	25	26	37.50	5.80
PT1	I intend to try out a smart contract in a limited scope in my works, before deciding whether to adopt it in practice.	1	10.60	12.50	53.80	22.10
PT2	A trial period before adopting a smart contract in practice will reduce my perceived risks.	0.00	5.80	12.50	47.10	34.60
PT3	Being able to try out a smart contract is important in my decision to adopt it in the future.	1	2.90	9.60	50	36.50
PO1	There is good publicity about the positive effects of smart contracts.	3.80	30.80	30.80	28.80	5.80
PO2	Other organisations using smart contracts liked using them.	4.80	6.70	56.70	26	5.80
PO3	I have a clear understanding of the positive effects of a smart contract.	5.80	25	26	37.50	5.80
PTMS1	Top management in my organisation is aware of the benefits that smart contracts can provide.	7.70	28.80	30.80	27.90	4.80
PTMS2	Top management influences employees to increase awareness of the importance/advantages that smart contracts can bring.	4.80	24	34.60	31.70	4.80
PTMS3	Top management provides adequate resources for employees to adopt smart contracts.	10.60	24	32.70	28.80	3.80
POR1	My organisation has the needed resources to support smart contract adoption.	5.80	20.20	26.90	36.50	10.60
POR2	Existing technologies in my organisation support smart contract adoption.	2.90	26.90	23.10	39.40	7.70
POR3	Information Technology (IT) staff within my organisation have adequate skills and experience to support smart contract adoption.	7.70	23.10	29.80	32.70	6.70
PCP1	The use of smart contracts would offer my organisation a stronger competitive advantage.	5.80	5.80	17.30	43.30	27.90
PCP2	The use of smart contracts would increase the ability of my organisation to outperform the competition.	2.90	4.80	26	42.30	24
PCP3	The use of smart contracts will allow the generation of higher profits to my organisation.	4.80	5.80	34.60	36.50	18.30
PCP4	My organisation has experienced competitive pressure to adopt smart contracts.	11.50	21.20	29.80	27.90	9.60
PCP5	My organisation would have experienced a competitive disadvantage if smart contracts had not been adopted.	8.70	16.30	39.40	26.90	8.70
PGS1	Government legislation supports the adoption of smart contracts.	7.70	16.30	38.50	30.80	6.70
PGS2	Legislation about smart contracts is transparent.	7.70	16.30	51.90	18.30	5.80
PGS3	Firms are legally protected through smart contacts.	7.70	9.60	49	36	7.70
PSCP1	My organisation's business partners recommend the adoption of smart contracts.	7.70	25	35.60	26.90	4.80
PCSP2	My organisation's business partners have requested the adoption of smart contracts.	9.60	26	36.50	24	3.80
PCSP3	My organisation has experienced pressure from business partners to adopt smart contracts.	13.50	22.10	40.40	18.30	5.80
UI1	My organisation intends to use smart contracts actively.	5.80	19.20	43.30	24	7.70
UI2	My organisation intends to actively recommend smart contracts to others.	5.80	19.20	42.30	26.90	5.80
UI3	My organisation intends to use smart contracts continuously on various projects.	7.70	20.20	46.20	21.20	4.80

facilitator of technology adoption across a wide range of industries (e.g. Oliveira and Martins 2010, Chandra and Kumar 2018). In the fiercely competitive environment of construction, firms may view the adoption of smart contracts as adding to their ability to serve their client (Badi *et al*. 2020). In this context, a smart contract may be seen to offer firms an edge that strengthens their competitive position against rival firms in the market (Gutierrez *et al*. 2015). Top management support is found to be the third most significant constituent for smart contract adoption. This finding concurs with previous studies that highlighted the role of top management support in encouraging technology adoption in organisations (Low *et al*. 2011, Chandra and Kumar 2018). Senior managers in construction firms play a major role in raising awareness of the benefits of smart contracts and act as catalysts for change in their organisations. Thus, top management support can help to reduce internal forces resisting change, cultivate a positive vision for the change, and communicate this vision among employees (Hayes 2014). Top management can also allocate the necessary IT resources and financial support required for the successful adoption of smart contracts in construction organisations.

Surprisingly, observability is found to be a barrier to smart contracts in this research study, which contradicts the findings of previous research on the importance of observability to technology adoption, such as Lin and Chen (2012) study of cloud computing. One possible reason for observability to emerge as a clear barrier to smart contract adoption is the limited publicity and use cases available for successful smart contract implementation in construction projects. Reflecting on the descriptive statistics presented in Table 7, about 35% of the respondents disagree that there is good publicity about the positive effects of smart contracts, while almost 57% do not know whether other organisations using smart contracts have had a positive experience using such contracts or not. On the same note, almost 43% of respondents do not have a clear understanding of the positive effects of a smart contract. This identified inability of construction practitioners to observe the positive advantages of smart contracts as opposed to traditional contracting systems will act as a barrier to the wider adoption of smart contracts in the industry.

Further analysis shows that there is no significant relationship between the remaining six variables examined and smart contract adoption, namely relative advantage, compatibility, non-complexity, trialability, organisational readiness, and government support. While these factors are seen to support the adoption of technologies in other studies (see Section 2 of this paper), their role in facilitating smart contracts was not proven in this study. Surprisingly, technological characteristics are found to be deficient in supplementing smart contract adoption as none of the five determinants examined showed significance. One explanation for this outcome may relate to the relative immaturity of the smart contract technology at present (Lauslahti *et al*. 2017). First, the perceived relative advantage was not determined to be a constituent of smart contract adoption. This finding is surprising, as a considerable proportion of our respondents, as shown in Table 7, believed that a smart contract reduces payout time (80%), reduces transaction cost (70%), and provides secured payments (65%). Moreover, 50% of respondents stated that a smart contract protects contracting parties from insolvencies and late payments, 60% viewed smart contracts as reducing the occurrence of disputes among contracting parties, and 58% affirmed that such contracts increase trust among contracting parties.

The compatibility of smart contracts with existing contractual systems is an issue that also requires attention. Whilst 59% of respondents perceived smart contracts to be compatible with the contract management needs of their organisation, and 58% considered smart contracts to be consistent with the existing values and beliefs of their organisations, only 33% of the respondents acknowledged that smart contracts are compatible with the existing contract management systems in their organisation. The compatibility of smart contracts with existing contractual systems thus requires further clarification to convince construction practitioners of their merits (Lauslahti *et al*. 2017). The compatibility of smart contracts was a concern raised by a recent European Parliament report (Boucher 2017) which observed that the variation inevitable in contracts with long durations generates problems for pre-coded smart contracts. The report also suggests that the initial costs of putting together a smart contract make these contracts more suitable for repetitive agreements than for one-off contracts.

The participants seemed to be undecided regarding non-complexity, with almost a quarter of respondents on average neither agreeing nor disagreeing about the complexity of smart contracts. Almost 50% of participants avowed that a smart contract is easy to understand, whilst 60% considered such contracts both easy to use and manageable. Forty-three percent of respondents confirmed that smart contracts are easy to integrate with existing contractual processes in their organisations. Based on this finding, it could be suggested that by switching to smart contracts construction organisations can experience automated and accurate operations and processing, guaranteeing non-complexity and conformity to regulations and requirements. For any construction organisation, management and operations can become a slow, tedious process susceptible to inaccuracy. Smart contracts can offer a positive solution by streamlining communication and providing acute accuracy automation of information.

Trialability has been identified to increase successful technology adoption in several studies (e.g., Kendall *et al*. 2001, Rogers 2003, Lin and Chen 2012, Ramdani *et al*. 2013). Trialability is strongly espoused by our respondents, with a significant 80% intending to try out a smart contract in a limited scope in their works before deciding whether to adopt it in practice, while 82% suggested that a trial period before adopting a smart contract in practice would reduce the perceived risks. Eighty-six percent of respondents agreed that being able to trial a smart contract is an important factor in their decision to adopt it in the future. As Table 7 indicates, organisational readiness appeared to be a contested issue among the respondents, with a quarter taking the neutral stance of neither agreeing nor disagreeing about whether their organisations have the needed resources, technologies, or skills to support smart contracts. That said, some respondents noted that their organisations have the needed resources (47%), supporting existing technologies (47%), and adequate IT staff skills and experience (39%).

The role of government in supporting the adoption of smart contracts was also observed to be unclear. Indeed, a considerable amount of our respondents were unable to provide a definitive view of the role of government support: 52% remained neutral on whether legislation regarding smart contracts is transparent, while 49% neither agreed nor disagreed that construction organisations are legally protected through smart contracts. Moreover, 38.5% of respondents were unable to ascertain whether government legislation is supporting the adoption of smart contracts or otherwise. These findings suggest that considerable effort must be undertaken to further illuminate these issues. While there is some movement towards increased government regulation in the UK (for example, see Vos 2019), more work needs to be done to elucidate the legal aspects of smart contracts.

Conclusion

The present study is designed to identify the key factors that influence the adoption of smart contracts in the UK construction sector. Utilising a perception-based model based on the TOE framework (DePietro *et al*. 1990), the study appraises factors that influence the adoption intention of smart contracts at the organisational level by assessing three primary TOE components: technological factors (relative advantage, compatibility, non-complexity, trialability, and observability), organisational factors (top management support and organisational readiness) and environmental factors (competitive pressure, government support, and supply chain pressure). The study found generally that the role of environmental and organisational factors is significant in influencing adoption, and it identifies supply chain pressure, competitive pressure, and top management support as the most important facets of smart contract adoption. The findings suggest that construction practitioners perceived smart contracts to be driven not by their technological characteristics, but rather by how such technology can be mobilised to implement new approaches to transacting that can add value to the organisation's competitive advantage and supply chain performance.

The theoretical contribution of the research can be regarded from three viewpoints:

- First, this study makes the first attempt to examine the drivers of smart contract adoption intention in the construction sector. Thus, the findings presented here make a noteworthy contribution to the growing literature in this fledgling area.
- Second, it was found that this study constitutes the first utilisation of the TOE framework to explore smart contract adoption, both generally and in the construction sector specifically. The framework has proven useful in examining a comprehensive set of technological, organisational, and environmental factors that may shape an organisation's inclusive decision-making process.
- Third, the study has gone some way towards appraising the role of supply chain pressure, competitive pressure, and top management support in the decision to adopt smart contracts in the construction sector. Taken together, these findings suggest a role for environmental and organisational factors in promoting smart contract adoption decisions in the construction sector.

The findings of this study have several important implications for future practice in the UK construction sector. The top management of construction firms should recognise the vital role they play in driving smart contract adoption. Top management support and commitment are found to be key constituents for smart contract adoption as senior managers are seen as the catalyst for this change in their organisations. To stay competitive in this increasingly digitised sector, it may become a requirement for senior managers to explore the use of smart contracts in their operation and liaise with their supply chain actors to streamline their operations and thereby reap the benefits of smart contracts. Top managers should thus consider enhancing their competence in the application of smart contract technology as well as smart contract management. This objective could be achieved by adopting a top-down model, with the knowledge and expertise originating at the upper levels of the organisation being diffused through education and communication to the lower-level employees (Kotter and Schlesinger 1979). Moreover, this study will be valuable to proponents of smart contracts, especially those management consultants and law firms who are exploring the provision of smart contracts as a service to their clients. The study has also provided useful insight into the factors that are significantly associated with smart contract adoption decisions. For instance, it has been shown that consultants can devote considerable attention to convincing top management of the benefits of smart contracts and the related competitive advantages to the firm's operations. Furthermore, consultants can accelerate smart contract adoption by leveraging the power of supply chain partners and promoting supply chain-wide solutions. The observability of the technological benefits of smart contracts could also be facilitated by generating good publicity for successful use cases. If well-devised, this approach could increase industry awareness of the advantages of smart contracts as opposed to traditional contracting systems.

Limitations and further research

The study findings are subject to several limitations that need to be acknowledged. First, although the scope of this research was restricted to UK construction practitioners, its limited geographical focus does not invalidate the study results with respect to other countries. The fact is that the global construction sector shares many common fundamental characteristics. The UK construction sector was simply used as a case study to examine broader issues and problems of smart contract adoption. Second, given the limited time and resources available for conducting the study, convenience sampling was considered the most effective strategy for selecting a representative group from the population under study. However, convenience sampling, as a non-probability sampling approach, could be seen as "subjective" given that the researchers included a sample from the selected population following the practical criteria of accessibility and willingness (Etikan *et al*. 2016). In this study, the participants included are those who were readily accessible to the researchers through their social networks and were willing to contribute their time to complete the questionnaire.

Finally, the study paves the way for future avenues of research. Smart contract adoption in construction remains in its embryonic stages, and future research could trace the diffusion of the innovation as it moves across the innovation curve from "early adopters" to "laggards" (Rogers 2003). In addition, the role of smart contracts in supply chain management is an area of potentially significant theoretical and managerial contributions and thus merits considerable attention (see for example Treiblmaier 2018). Furthermore, the issue of the legal standing of a smart contract is an unexplored theme which could be usefully examined. As a mechanism for the administration of contractual processes, a smart contract is a useful tool. However, there is considerable legal complexity beyond this aspect of smart contracts, which inevitably gives rise to concerns. Indeed, technological developments of smart contracts need to be firmly coupled with a greater understanding of the relevant laws and regulations. Consequently, further research needs to examine more closely the integration of smart contracts into project management processes. A smart contract is only one small part of any technology solution for a construction project. A network of interactive and interacting smart contracts would be necessary to provide an effective project governance regime and should be viewed as part of the wider BIM-led revolution in construction (Mason 2017). BIM coupled with smart contracts can produce a robust and trustworthy collaborative platform advocated by many in the industry (Winfield and Rock 2018).

Disclosure statement

No potential conflict of interest was reported by the author(s).

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