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ARTICLES (PEER REVIEWED)

Risk Level of Blockchain-Related Barriers in Contract Management within the Polish Construction Industry

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Abstract

A significant research gap exists in understanding how blockchain-related barriers affect contract management in the Polish construction industry, particularly in terms of the risks that these barriers pose to implementation. The aim of this study was to identify the key barriers to blockchain adoption and to evaluate the risk level associated with each barrier. Using the failure mode and effects analysis (FMEA) approach, a systematic review of the literature published between 2015 and 2024 was conducted to identify blockchain adoption barriers relevant to contract management. Purposive and snowball sampling targeted 45 qualified construction professionals in Warsaw, and a structured, expert-validated questionnaire was used to rate each barrier based on severity, occurrence, and detection. The FMEA enabled prioritization of blockchain-related risks according to their risk priority number (RPN), distinguishing low, moderate, and high-risk barriers. The findings reveal that the shortage of blockchain experts and the complexity of blockchain models pose the highest-risk barriers, while high implementation costs and limited client interest fall within the moderate-risk category. Recommended strategies include targeted capacity-building programs, simplification of blockchain system design, and collaborative funding.

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By clearly distinguishing between barriers (what obstructs adoption) and risks (the potential impact of those barriers), this study provides a structured, evidence-based foundation for improving blockchain adoption and strengthening digital transformation in Polish construction contract management.

Keywords

Blockchain Technology; Contract Management; Polish Construction Industry; Risk; FMEA

Introduction

The construction industry is well-known for its fragmented structure, involving numerous parties with varying interests in each project. This fragmentation often results in inefficiencies, low productivity, and suboptimal project outcomes ([Shojaei, 2019](#)). Over the years, technological advancements have been introduced to address these challenges ([Hultgren & Pajala, 2018](#)). Among these innovations, blockchain technology has emerged as a transformative tool capable of addressing long-standing inefficiencies by providing secure, decentralized, and transparent data management throughout the construction project life cycle ([Wu et al., 2017](#)). Thus, there is a pressing need to explore how blockchain technology can improve contract management, a critical aspect of construction projects plagued by delays, disputes, and mismanagement ([Singh et al., 2023](#)).

Traditional contract management practices in the construction industry rely heavily on manual workflows, paper documentation, and centralized systems prone to errors, delays, and miscommunication ([Azhar, 2011](#)). These practices often lead to contract breaches, resource mismanagement, and project delays, exacerbating inefficiencies ([Peters et al., 2019](#)). Blockchain technology, with smart contract self-executing contracts with terms coded directly into algorithms, offers an opportunity to address these inefficiencies ([Penzes, 2018](#)). By providing immutable transaction records and ensuring access to unalterable data for all stakeholders, blockchain can enhance trust, reduce disputes, and streamline contract management processes ([Bilal et al., 2016](#); [Ham et al., 2016](#); [Santos et al., 2017](#)). Despite these benefits, blockchain adoption in construction, particularly in contract management, has been slow, with Poland being a notable example of this reluctance ([Ameyaw et al., 2024](#)).

The Polish construction industry, like many traditional markets, has been slow to adopt blockchain technology. The industry heavily relies on conventional practices, emphasizing manual workflows and paper-based systems, which contribute to inefficiencies in project delivery and contract management ([Morawiec & Sołtysik-Piorunkiewicz, 2022](#)). Moreover, there is a general reluctance among Polish construction professionals to embrace innovative technologies due to a lack of awareness, limited understanding of blockchain's benefits, and resistance to changing long-established processes ([Zima et al., 2020](#)). These challenges are compounded by the high costs of implementation and the complexity of integrating blockchain systems into existing workflows ([Zawada et al., 2024](#)).

Previous research has extensively explored blockchain technology's potential to enhance construction practices across various regions. For instance, studies in China have focused on integrating blockchain with artificial intelligence for improved project management efficiency ([Li et al., 2021](#)). Research in the United States has emphasized the technology's ability to foster trust and collaboration among project stakeholders ([Wu et al., 2022](#)). In the United Kingdom, attention has been given to blockchain's role in resolving disputes through transparent and immutable record-keeping ([Li & Kassem, 2021](#)). Meanwhile, in South Africa, studies have addressed the cultural and regulatory challenges that hinder blockchain adoption in construction ([Dowelani et al., 2022](#)). Within Poland, research on blockchain adoption in construction has primarily addressed its potential for digital transformation in broader construction practices ([Zima et al., 2020](#); [Ameyaw et al., 2024](#); [Singh et al., 2023](#)). However, these studies have not specifically examined the barriers to adopting blockchain technology for contract management, which is a critical component

of project success. The lack of research addressing this niche, particularly in the context of the Polish construction industry, leaves a significant gap in understanding how blockchain can address inefficiencies, disputes, and mismanagement that are prevalent in traditional contract workflows.

This study aimed to identify the key barriers to blockchain adoption and to evaluate the risk level associated with each barrier within the Polish construction industry. Unlike general studies that broadly explore blockchain's potential in construction, this research focuses on identifying practical and systemic risks unique to Poland. These include the industry's reliance on traditional practices, resistance to technological change, and the lack of regulatory frameworks supporting blockchain-based contracts. By filling this research gap, the study not only advances the body of knowledge on blockchain adoption in construction but also lays the groundwork for a transformative shift in how contracts are managed within the Polish construction industry, as discussed by [Treiblmaier \(2018\)](#). Information-sharing obstacles and integration problems further complicate the adoption process, with [Andrychowicz et al. \(2015\)](#) and [Öztürk and Yildizbaşı \(2020\)](#) highlighting challenges in information exchange and interoperability. [Swan \(2015\)](#) emphasized the need for standardization to avoid technological constraints during integration. Additionally, the industry is vulnerable to malware issues due to often inadequate cybersecurity measures, which pose significant risks ([Andrychowicz et al., 2015](#); [Treiblmaier, 2018](#)). Undefined application risks also contribute to the hesitation in adopting blockchain, as companies are uncertain about the potential legal and financial repercussions ([Paech, 2018](#)).

Literature review

OVERVIEW OF BLOCKCHAIN TECHNOLOGY IN CONSTRUCTION

The notion of blockchain technology was recognized as early as 1991 when academics Stuart Haber and W. Scott Stornetta devised a practical computer technique for time-stamping digital records so that they could not be backdated or manipulated ([Haber & Stornetta, 1991](#)). The system employed a cryptographically secure chain of blocks to store time-stamped documents. Merkle trees were integrated into the architecture in 1992, making it more efficient by allowing the collection of many documents in one block ([Haber & Stornetta, 1992](#)). However, this technique never materialized, and the patent expired in 2004 ([Haber & Stornetta, 2004](#)), 4 years before Bitcoin was launched. Bitcoin came into existence on 3 January 2009 when Satoshi Nakamoto mined the first Bitcoin block ([Nakamoto, 2008](#)). There was a common misconception that Bitcoin and blockchain were synonymous. However, it was not until 2014 that people began to recognize blockchain's potential beyond cryptocurrency, leading to increased investment and exploration of its application across various industries ([Mojeed, 2021](#)).

Blockchain is a decentralized, encrypted digital ledger that records data across a distributed network of computers, ensuring that information is transparent and immutable ([Wright & De Filippi, 2015](#)). Each data record, or "block", is linked to others in a chronological "chain", and once added, it cannot be altered or deleted. This technology operates through automated protocols that ensure the integrity of transactions and enable shared governance ([Christidis & Devetsikiotis, 2016](#)). Every participant in the blockchain network maintains a copy of the ledger, eliminating the need for a central authority while promoting transparency and trust ([Swan, 2015](#)). [Azure \(2016\)](#) pointed out that blockchain technology streamlines business processes by allowing for near-instantaneous verification of transactions, reducing costs and minimizing the risk of fraud.

In comparison to traditional contract management, which involves the creation, execution, and monitoring of agreements between parties to ensure compliance with agreed terms, traditional contract management systems often rely on manual processes, paper documentation, and centralized databases, making them prone to delays, errors, and disputes due to miscommunication and the reliance on human

workflows ([Love et al., 2010](#)). Blockchain, by contrast, automates the execution of contract terms through smart contracts, ensuring accuracy and reducing the risk of disputes ([Penzes, 2018](#)). Integrated with building information modeling (BIM), blockchain enhances transparency, accountability, and traceability through the supply chain, improving the overall efficiency of construction projects ([Shojaei, 2019](#); [Queiroz et al., 2019](#)). Additionally, blockchain's immutable records improve facility management and asset life cycle tracking, ensuring long-term operational efficiency ([Mathews et al., 2017](#)).

BARRIERS INHIBITING BLOCKCHAIN'S ADOPTION IN CONSTRUCTION INDUSTRY

The barriers to blockchain adoption identified in this study were selected through a systematic review of literature published between 2015 and 2024, focusing on studies relevant to the construction industry. Inclusion criteria prioritized research that explicitly addressed technical, operational, managerial, and regulatory challenges associated with blockchain implementation. Only peer-reviewed articles, published in English and available in full text, were considered to ensure credibility and relevance. This approach ensured that the selected articles reflect the critical challenges highlighted in contemporary literature, providing a robust foundation for understanding the impediments to blockchain adoption in construction.

A significant challenge is the high initial cost of implementation, as noted by [Öztürk and Yildizbaşı \(2020\)](#). Blockchain technology, particularly in the context of mining, requires substantial electrical energy and highly skilled human resources, leading to significant operational expenses ([Öztürk & Yildizbaşı, 2020](#); [Belle, 2017](#); [Perera et al., 2020](#)). The scarcity of qualified personnel to manage open-source platforms further exacerbates these costs, making it difficult for many construction companies to justify the investment ([Belle, 2017](#); [Perera et al., 2020](#)). Additionally, the immaturity of blockchain technology presents another significant hurdle, particularly in terms of scalability and storage management. As [Öztürk and Yildizbaşı \(2020\)](#) noted, blockchain struggles with handling large volumes of transactions and storing the ever-increasing blocks of data, which is a critical requirement for large-scale construction projects. The inherent complexity of the technology also necessitates upgrades to existing infrastructure, further driving up implementation costs. The need for high computational power and ongoing scalability issues only compounds these challenges, making it difficult for companies to seamlessly integrate blockchain into their operations ([Andoni et al., 2019](#); [Viktorovich, 2020](#)).

Another critical barrier is the widespread lack of awareness about the potential benefits of blockchain technology within the construction industry. Many professionals in the field are not fully informed about how blockchain can enhance transparency, efficiency, and security in project management and operations ([Hunhevciz & Hall, 2019](#); [Li et al., 2019](#)). This gap in knowledge is a significant impediment to adoption, as it prevents industry stakeholders from recognizing the value that blockchain could bring to their projects. Compounding this issue is a deep-seated resistance to change, which is pervasive in the construction industry. Known for its reliance on traditional methods, the industry often exhibits reluctance to embrace new and unproven technologies. This resistance is largely driven by skepticism and fear of the unknown, both of which hinder the adoption of blockchain technology ([Hunhevciz & Hall, 2019](#); [Li et al., 2019](#)). Additionally, the negative perception toward emerging technologies, intellectual property concerns, and fragmented smart contract processes further contribute to the industry's resistance to blockchain adoption ([Andoni et al., 2019](#); [Perera et al., 2020](#)). Furthermore, the lack of demand from contractors, coupled with the absence of incentives or rewards for adopting blockchain technology, creates a significant barrier to its widespread use ([Jardim, 2020](#); [Kamble et al., 2019](#)). Without a clear demand or motivation for adoption, stakeholders are less likely to invest in and experiment with blockchain technologies.

[San et al. \(2019\)](#) highlighted insufficient governmental support as a significant barrier, with regulatory uncertainty posing a difficulty. Some countries ban blockchain technology due to its potential impact on the economy through criminal activities, uncontrolled currency, and financial outflow. [Mougayar \(2016\)](#) and [Mathivathanan et al. \(2021a\)](#) noted that unfavorable government policies contribute to this issue. Without

Table 1. Barriers inhibiting blockchain adoption in the construction industry.

Code	Barriers	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
B1	Insufficient government support													☒	☒			☒			
B2	High initial implementation cost															☒					
B3	Inadequate training programs						☒						☒								
B4	Limited awareness of blockchain benefits						☒						☒								
B5	Resistance to adopting changes in industry culture						☒						☒								
B6	Limited client interest																				
B7	Lack of support from senior management							☒													☒
B8	Shortage of blockchain expert																☒				
B9	Absence of standardized tools			☒														☒			
B10	Complexity of blockchain model	☒																		☒	
B11	Immature blockchain technology landscape									☒											
B12	Insufficient innovation																		☒		
B13	Negative perception towards blockchain technology	☒																	☒		
B14	Vulnerability to malware		☒																☒		
B15	Liability among stakeholders			☒														☒			
B16	Concerns over intellectual property rights	☒															☒				
B17	Low demand from the contractors										☒	☒									
B18	Extended development timelines for blockchain model																		☒		
B19	Legal and regulatory issues				☒												☒				
B20	Challenges with information disclosure policies between parties		☒			☒															
B21	Undefined application risk																☒				
B22	High computational power requirements																			☒	
B23	Scalability and storage issues									☒											

A, [Andoni et al. \(2019\)](#); B, [Andrychowicz et al. \(2015\)](#); C, [Belle \(2017\)](#); D, [Deshpande et al. \(2017\)](#); E, [Govindan and Hasanagic \(2018\)](#); F, [Hunhevicz and Hall \(2019\)](#); G, [Ivanov et al. \(2019\)](#); I, [Öztürk and Yildizbaşı \(2020\)](#); J, [Jardim \(2020\)](#); K, [Kamble et al. \(2019\)](#); L, [Li et al. \(2019\)](#); M, [Mathivathanan et al. \(2021b\)](#); N, [Mougayar \(2016\)](#); O, [Öztürk and Yildizbaşı \(2020\)](#); P, [Paech \(2018\)](#); Q, [Swan \(2015\)](#); R, [Treiblmaier \(2018\)](#); S, [Viktorovich \(2020\)](#); T, [Yang \(2019\)](#).

clear regulatory frameworks and supportive policies, companies are reluctant to invest in blockchain, fearing potential legal and financial repercussions. [Yang \(2019\)](#) and [Ivanov et al. \(2019\)](#) discussed management's hesitation to adopt new technologies ([Deshpande et al., 2017](#); [Paech, 2018](#)). This reluctance is driven by concerns about the long-term viability of blockchain, the costs involved, and the uncertainty surrounding its benefits. Managers who are not committed to the long-term adoption of blockchain can significantly hinder its implementation, as they may be unwilling to allocate the necessary resources or champion the technology within their organizations.

The lack of research and development units and human resource policies also hinder adoption, as discussed by [Treiblmaier \(2018\)](#). These barriers, as outlined in [Table 1](#), collectively impede the widespread adoption of blockchain technology in construction.

Methodology

RESEARCH DESIGN AND SAMPLING PROCESS

A purposive sampling technique was adopted to select respondents who possessed specific characteristics relevant to the study. The targeted population included construction professionals with experience in contract management, such as project managers, contract administrators, engineers, and procurement officers, working in Warsaw, Poland. These individuals were selected because of their knowledge of contract workflows and their exposure to digital technologies in construction. This approach ensured the recruitment of participants who could provide informed perspectives on the barriers to blockchain adoption in contract management. Additionally, snowball sampling was employed to expand the respondent pool. Initial participants were asked to recommend other qualified professionals within their networks. This method was particularly effective in reaching respondents with expertise in contract management while overcoming the challenges of accessing a specialized population within the limited study timeframe. These combined sampling techniques enhanced the representativeness and relevance of the data collected, as purposive sampling allows the selection of participants with the precise knowledge required for the research problem ([Patton, 2015](#)). The use of purposive and snowball sampling ensured the inclusion of knowledgeable respondents, increasing the study's reliability and relevance to contract management in the Polish construction industry. Snowball sampling further strengthened the process by enabling initial participants to refer to other qualified professionals within their networks ([Noy, 2008](#); [Etikan et al., 2016](#)).

The questionnaire was structured into two main sections: first, background information, which captured demographic details such as the respondents' roles, years of experience in the construction industry, and familiarity with blockchain technology. The second section presented a list of identified barriers to blockchain adoption, and respondents were asked to evaluate each barrier in terms of severity, occurrence, and detection, reflecting its potential effect on blockchain adoption. To ensure content validity, the questionnaire was pretested with five industry experts who provided feedback on its clarity, comprehensiveness, and relevance. Adjustments were made based on their recommendations before distributing the survey via Google Forms and email. A total of 67 questionnaires were distributed, with 51 responses received. After data cleaning, 45 valid responses were included in the analysis, representing a response rate of 67%, which aligns with best practices for similar studies in construction research. Following data collection, the internal consistency reliability of the questionnaire was assessed using Cronbach's alpha, a widely accepted measure of scale reliability in social and construction research ([Tavakol and Dennick, 2011](#)). All constructs achieved alpha values above the recommended threshold of 0.70, indicating satisfactory reliability and consistency in measuring blockchain adoption barriers.

METHOD OF DATA ANALYSIS

The data collected for this study were analyzed using a combination of descriptive statistics and failure mode and effects analysis (FMEA). Descriptive statistics, including percentages and frequency distributions, were employed to summarize the demographic and background information of the respondents. This approach enabled the establishment of a clear profile of participants, providing insight into their characteristics, experiences, and perspectives relevant to the study.

FMEA tool was utilized to assess and prioritize the identified barriers to blockchain adoption in contract management by linking each barrier to its associated risk. Each barrier represents a potential source of failure in the adoption process, such as high implementation costs, lack of awareness, or technological immaturity. By evaluating the severity, occurrence, and detection (S, O, and D) of these barriers, it becomes possible to quantify the potential impact, likelihood, and detectability of each barrier as a “risk” to successful adoption. In this way, risks act as measurable proxies for the barriers, allowing systematic comparison and prioritization. Barriers that score high on severity, occurrence, and detection pose higher risks to project outcomes, making the FMEA methodology a suitable tool for identifying the most critical impediments.

These three parameters, assessed using 45 valid responses, were approximated to whole numbers to ensure a whole-number risk priority number (RPN). Each parameter is scored on a scale of 1 to 10, where 1 represents the lowest level and 10 represents the highest (Stamatis, 2003), and their product determines the RPN. The RPN, ranging from 1 to 1,000, categorizes risks into three levels with specific tolerance and response requirements (see Table 2). FMEA allowed for a systematic evaluation of the most critical barriers hindering blockchain adoption in contract management. The FMEA approach was used to identify the most critical issues. The RPNs are classified on a scale of 1–300 (low), 301–500 (moderate), and 501–1,000 (high), indicating the need for immediate attention (Carlson, 2012).

By quantifying the risk associated with each barrier, this method provided actionable insights, leading to the formulation of targeted strategies that could assist in overcoming the challenges specific to the Polish construction industry. This methodological approach ensured a rigorous and comprehensive examination of the barriers to blockchain adoption in contract management, contributing to actionable strategies for the Polish construction industry. A representation of the adopted methodology is shown in Figure 1.

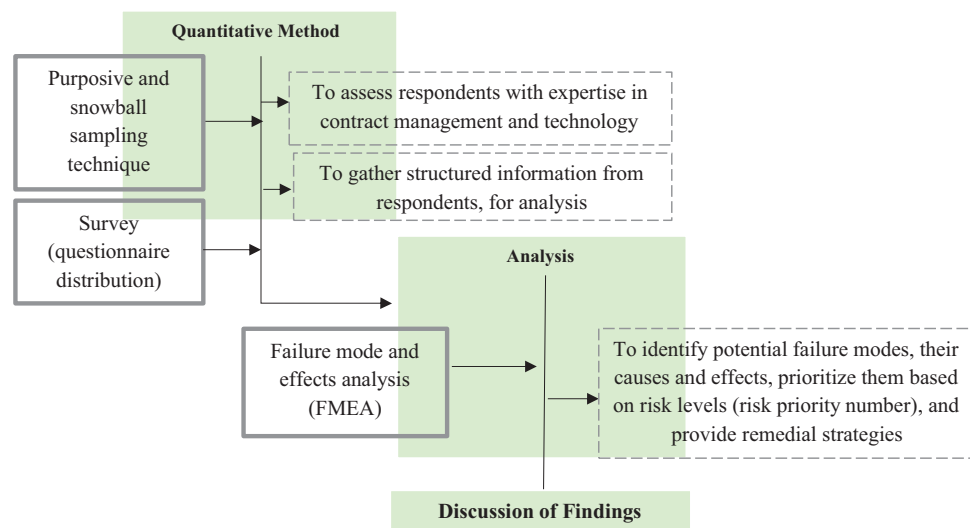


Figure 1. Research methodology adopted.

Table 2. Risk classification for blockchain-related barriers in contract management.

Category	Description	Range	Notes
Risk evaluation			
Detection	Relevance	1–10	
Occurrence	Likelihood of occurrence	1–10	
Severity	Potential impact	1–10	
Risk priority	Multiplied result of detection, occurrence, and severity	1–1,000	Detection value × Occurrence value × Severity value
Risk category			
1–300	Can be tolerated	Low	Risks in this category have a low probability or impact and can be tolerated without immediate action.
301–500	Requires monitoring, barely tolerable	Moderate	These risks require monitoring and mitigation strategies to prevent escalation, although they do not pose an immediate threat.
501–1,000	Cannot be tolerated, requires immediate action	High	These risks demand urgent attention, as they can have significant adverse effects on blockchain implementation or performance.

Results

BACKGROUND INFORMATION OF RESPONDENTS

[Table 3](#) outlines the professions, project experience, and blockchain involvement of respondents in the construction sector. Project managers represent the largest group (22.22%), followed by architects and cost engineers (20% each). Clients make up 17.78%, while contractors (13.33%) and others (6.67%) are from smaller groups. Regarding project experience, 46.67% of the respondents have worked on more than eight construction projects, with few involved in one to eight projects. Notably, 73.33% of the respondents have experience with blockchain implementation in their projects, while 26.67% do not. This suggests that blockchain technology is gaining traction among experienced construction professionals across various roles.

The FMEA identified and prioritized 23 barriers to blockchain adoption in contract management based on their RPN, as presented in [Table 4](#). High-risk barrier ($RPN \geq 500$) includes overly complicated technical design (B10, RPN 729) and difficulty finding qualified professionals (B8, RPN 576), highlighting critical technical and skills-related challenges. Moderate-risk barriers ($RPN 301\text{--}500$) encompass unaffordable infrastructure, organizational inertia, low perceived value, lack of top-down commitment, industry-wide tool gaps, public cybersecurity threats, unclear regulations, and inadequate risk management strategies. Low-risk barriers ($RPN \leq 300$) include issues such as lack of a regulatory framework, limited understanding of blockchain advantages, disputes over content ownership, delays, and unclear contractual obligations. Overall, the analysis shows that technical complexity, workforce skills, and organizational commitment are

Table 3. Background information.

Variables	Classification	Frequency	Percentage (%)
Profession	Project manager	10	22.22
	Architect	9	20.00
	Clients	8	17.78
	Cost engineers	9	20.00
	Contractors	6	13.33
	Others	3	6.67
Number of construction projects undertaken	1–2 projects	4	8.89
	3–4 projects	6	13.33
	5–6 projects	8	17.78
	7–8 projects	6	13.33
	Above 8 projects	21	46.67
Respondent's involvement in blockchain implementation	Yes	33	73.33
	No	12	26.67

the most significant impediments, while legal, regulatory, and awareness-related barriers are less critical. The systematic approach provided by the detection, occurrence, and severity ratings facilitates an organized evaluation of risks, enabling the prioritization of efforts to address the most critical issues. Based on the failure modes, those with the highest RPN were prioritized for the development of appropriate remediation strategies. The overall classification of the identified barriers into high-, moderate-, and low-risk categories is presented in [Figure 2](#).

Discussion

This study engaged 45 carefully selected professionals in Warsaw with expertise in contract management and exposure to digital technologies, including blockchain. Purposive and snowball sampling ensured the inclusion of highly knowledgeable participants, enhancing the relevance and credibility of the findings. A key contribution lies in applying the FMEA to systematically quantify and prioritize adoption barriers, an approach rarely used in prior research. By evaluating risks through detection, occurrence, and severity to generate an RPN, barriers were classified as low, moderate, or high, enabling targeted analysis and formulation of tailored mitigation strategies.

When compared to studies in other regions, several parallels and distinctions emerge. For instance, risk classification in the United States emphasizes severity and occurrence, like Poland, but often integrates financial quantification for prioritization ([Wu et al., 2022](#)). Meanwhile, studies in China rely less on numeric risk scoring and more on qualitative assessments guided by expert judgment ([Li et al., 2021](#)). Unlike Poland's nuanced inclusion of moderate risks, Indian studies typically classify risks as high or low, focusing primarily on external factors such as government policies and client readiness ([Singh et al., 2023](#)). Germany places significant emphasis on financial risks, such as the economic feasibility of blockchain, while Australian studies expand the scope to include environmental and socio-political factors in smart contracts

Table 4. FMEA on the barriers to blockchain in contract management within the Polish construction industry.

Code	Potential failure modes (Risk)	Effects	Detection	Occurrence	Severity	Risk priority	Risk category
B1	Lack of regulatory framework for blockchain adoption	Slow adoption, lack of trust in technology, hindered innovation	5	7	6	210	Low
B2	Unaffordable blockchain infrastructure	Delays in adoption, reluctance to invest, limited implementation	7	8	8	448	Moderate
B3	Lack of skilled workforce	Inability to use blockchain effectively, slow adoption	5	6	6	180	Low
B4	Low understanding of blockchain advantages	Poor adoption rates, industry skepticism	6	6	7	252	Low
B5	Organizational inertia	Slow adoption, reluctance to change, missed opportunities	7	7	7	343	Moderate
B6	Low perceived value or understanding of blockchain	Stagnation in blockchain projects, lack of demand	8	7	8	448	Moderate
B7	No top-down commitment to blockchain integration	Project abandonment, lack of resources or attention	7	7	7	343	Moderate
B8	Difficulty finding qualified professionals	Slow project progress, quality issues, skills gap	8	8	9	576	High
B9	Lack of industry-wide tools for development and implementation	Increased project complexity, inefficiency, integration issues	7	7	8	392	Moderate
B10	Overly complicated technical design	Low user adoption, implementation delays, operational inefficiencies	9	9	9	729	High
B11	Unreliable or untested blockchain solutions	Risk of project failure, incompatibility, technical issues	6	6	7	252	Low
B12	Lack of breakthrough ideas or solutions	Stagnant progress, inability to meet market needs	6	6	7	252	Low
B13	Public skepticism or misinformation about blockchain	Low adoption rate, fear or resistance from users	5	5	6	150	Low
B14	Blockchain platform being attacked by malicious software	Data loss, compromised security, loss of trust in technology	7	7	8	392	Moderate
B15	Ambiguity in contractual obligations and responsibilities	Legal disputes, project delays, loss of collaboration	6	5	7	210	Low
B16	Disputes over ownership of blockchain-developed content	Lawsuits, delay in development, reluctance to share technology	6	6	7	252	Low
B17	Lack of need for blockchain in contractors' operations	Blockchain adoption delayed, low project engagement	5	7	7	245	Low
B18	Delays in blockchain project delivery	Missed deadlines, increased costs, loss of investor confidence	7	6	7	294	Low
B19	Unclear or conflicting regulations regarding blockchain usage	Compliance issues, delays in launch, possible legal sanctions	7	8	8	448	Moderate
B20	Difficulty in sharing data securely and efficiently between parties	Breach of confidentiality, slow data exchange, legal concerns	6	5	4	120	Low
B21	Unclear risk management strategies	Increased likelihood of failure, unanticipated risks	8	7	7	392	Moderate
B22	High energy and hardware costs to maintain blockchain systems	Increased operational costs, unsustainable project model	6	7	7	294	Low
B23	Blockchain system unable to scale efficiently	Slower processing times, increased costs, system crashes	7	6	7	294	Low

FMEA, failure mode and effects analysis.

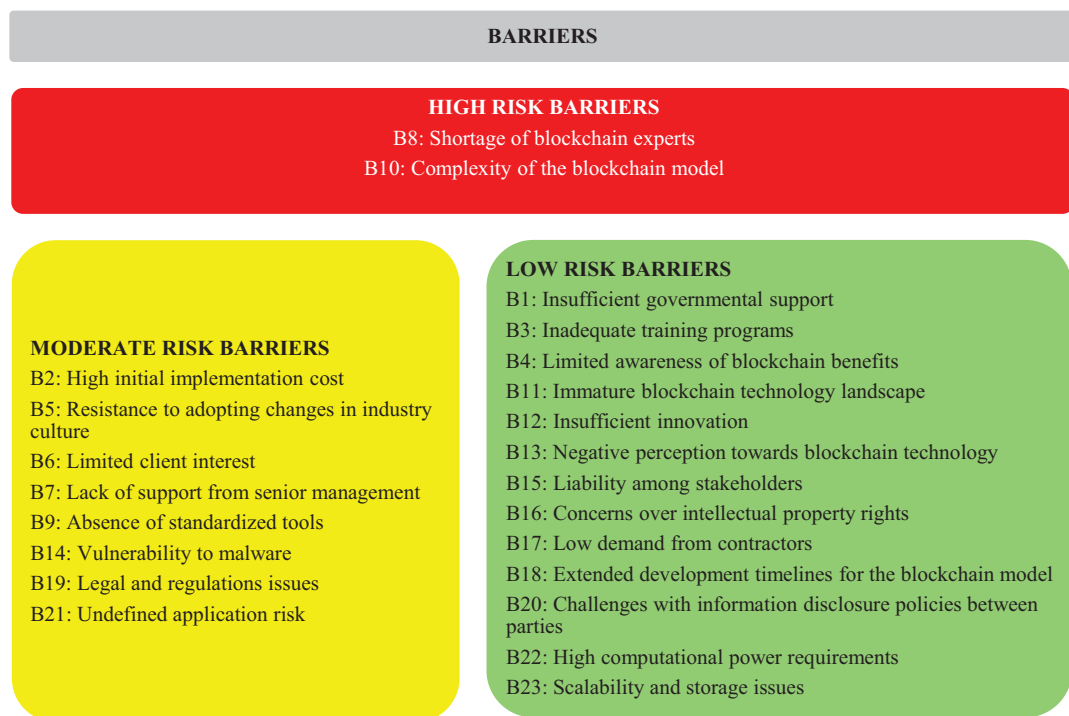


Figure 2. Risk category on the barriers to blockchain in contract management within the Polish construction industry.

delivery ([Kouhizadeh et al., 2023](#); [Ameyaw et al., 2024](#)). In contrast, Poland's framework provides a focused, structured, and quantitative approach that addresses both technical and operational risks.

The FMEA further highlights shared challenges, such as the shortage of blockchain experts, a common barrier in Poland and South Africa ([Dowelani et al., 2022](#)). In response, both regions emphasize collaboration with educational institutions and training programs. Similarly, high implementation costs are a significant economic barrier in Poland and China, although China often adopts public-private partnerships as a solution, while Poland recommends phased funding and cost-sharing models ([Liao et al., 2024](#)). Regulatory challenges, such as data protection and intellectual property concerns, align Poland's findings with those in Germany ([Kaczmarek-Templin, 2023](#)). However, Poland's inclusion of liability among stakeholders adds a unique dimension. Unlike Poland, which categorizes fragmented smart contracts as a high-risk technological barrier, regions like South Africa prioritize overcoming broader adoption resistance due to limited awareness of blockchain's potential ([Otasowie et al., 2023](#)).

This comparative analysis underscores the universality of some challenges, such as security concerns and expertise shortages, while highlighting Poland's distinct contributions to blockchain research. By addressing barriers with tailored mitigation strategies, the study not only advances blockchain adoption in Poland but also provides valuable insights that could inform similar efforts in other regions. These findings emphasize the importance of region-specific frameworks while identifying opportunities for cross-regional learning and collaboration in overcoming barriers to blockchain implementation.

RECOMMENDATIONS AND IMPLICATIONS OF THE STUDY

The study highlights critical barriers to adopting blockchain technology in contract management within the Polish construction industry and provides actionable recommendations to address them. High-risk barriers, such as the complexity of blockchain models, require specialized training programs to equip

existing professionals with the necessary skills to implement and manage blockchain technology. Suggested remedies also include simplifying blockchain models, strengthening encryption, adopting standardized smart contract protocols, and investing in training programs ([Li et al., 2021](#)). These programs should be tailored to the construction sector, focusing on blockchain fundamentals, smart contract development, and security protocols, with practical applications. Collaborations between universities, industry associations, and blockchain technology providers are essential to bridge this skill gap. Additionally, offering incentives such as financial support for blockchain certifications and ongoing education will help cultivate a pool of qualified experts, ensuring that the industry is prepared to adopt blockchain successfully. Moderate risks, such as high initial implementation costs and limited client interest, are addressed through phased funding, cost-sharing strategies, and targeted awareness campaigns to demonstrate return on investment ([Wu et al., 2022](#)).

Furthermore, the study emphasizes the complexity of blockchain models as a significant barrier to adoption. Simplifying blockchain technology is crucial for making it more accessible to construction industry stakeholders. The development of user-friendly platforms and interfaces that abstract the technical complexities of blockchain will enable non-technical users to engage with the technology. It is recommended that blockchain developers work closely with construction professionals to create solutions tailored to the industry's unique needs, ensuring that the technology is secure, scalable, and practical.

The limitations of this study include its focus on construction professionals within Warsaw, Poland, which may limit the generalizability of the findings to other regions or countries with different regulatory, technological, or organizational contexts. Future research could expand the geographical scope, increase sample size, or use case study approaches to validate and extend these findings.

Theoretical contribution

This study contributes to the growing body of knowledge on blockchain adoption by offering a detailed risk classification framework tailored to contract management in the construction industry. Leveraging the FMEA approach, it provides theoretical insights into categorizing blockchain-related barriers into high, medium, and low risks. By linking risk levels to actionable mitigation strategies, the research demonstrates how structured risk evaluation can directly inform practical adoption roadmaps. Furthermore, it underscores blockchain's potential to address entrenched inefficiencies in construction workflows and establishes a transferable framework for guiding implementation strategies in other industries and regional contexts.

Managerial implications

The findings offer actionable insights for managers and stakeholders in the Polish construction industry to address blockchain adoption barriers effectively. Managers should prioritize mitigating high-risk challenges like fragmented smart contract processes and security concerns by adopting robust security protocols and standardized frameworks. Additionally, targeted awareness campaigns can boost client interest, while phased funding and cost-sharing models can alleviate financial burdens. By investing in expert training and fostering collaboration among industry leaders and policymakers, managers can create an enabling environment for blockchain implementation, driving efficiency and transparency in contract management practices.

CONCLUSION AND FUTURE STUDIES

The adoption of blockchain technology in contract management within the Polish construction industry faces significant barriers that hinder its widespread implementation. This study addressed these barriers by employing a structured methodology using an FMEA framework to assess risks and propose practical solutions. The research analyzed blockchain-related barriers obtained from extant literature and

systematically categorized them based on their detection, occurrence, and severity. Key findings reveal that high-risk barriers, including the complexity of blockchain models and shortage of blockchain experts, require urgent attention. Moderate risks, such as high implementation costs and limited client interest, emphasize the need for strategic awareness campaigns and phased funding approaches. By prioritizing these challenges, stakeholders can focus on developing simplified models, enhancing security measures, and fostering collaboration within the industry. This study is essential, as it provides actionable insights for addressing the specific challenges of blockchain adoption in the Polish construction sector. Future research could expand this analysis to other regions or explore the long-term effects of these mitigation strategies on contract management. Collaborative efforts between academia and industry are also recommended to foster innovation and promote blockchain's full potential in construction.

Data availability statement

Some or all data, models, or code that support the findings of this study are available from the corresponding author upon reasonable request.

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