

SMART CONTRACT APPLICATIONS FOR MITIGATING DISPUTES IN THE CONSTRUCTION INDUSTRY

R.M.O.H. Bandara¹, M.D.T.E. Abeynayake², I.E. Illeperuma³, and B.A.I. Eranga⁴

ABSTRACT

Disputes frequently arise in construction projects due to the complexity of the processes and challenging environment, resulting in cost overruns, delays, wastage, and low productivity. Thus, the Construction Industry (CI) is enthusiastic about innovative dispute mitigation measures by incorporating digital technologies. Consequently, Smart Contracts (SCs) have emerged as a pioneering approach to digitise construction contracts and thereby mitigate construction disputes. Accordingly, this research aims to investigate the applications of SCs to mitigate disputes in the Sri Lankan CI. The research aim was approached through an explanatory mixed method. Initially, a questionnaire survey was carried out to collect quantitative data which was followed by qualitative expert interviews. Quantitative data were statistically analysed through Mean Weighted Average (MWA) and Relative Importance Index (RII) whereas qualitative data were analysed through content analysis. The study identified the root causes of construction disputes in the Sri Lankan context as poorly written contracts, poor preparation and approval of drawings, lack of communication and coordination, poor supervision and site management, and contain of contradictory and inaccurate information in the contract documents. The findings highlighted that SCs can significantly reduce construction disputes by replacing ambiguous processes with clear, automated processes. By linking payments to milestones, storing project data transparently, and potentially triggering actions based on safety or quality data, SCs streamline communication, ensure everyone plays by the agreed-upon rules, and thereby minimise disputes. Future researchers are suggested to explore the practical challenges and strategies for implementing SCs in the Sri Lankan CI.

Keywords: *Disputes; Mitigation; Smart Contracts; Sri Lanka.*

1. INTRODUCTION

The inherent complexity and the challenging operational environment of the CI lead to disputes that have detrimental effects on projects such as cost overruns, project delays, high wastage, and low productivity (Kisi et al., 2020; EI-Sayegh et al., 2020). Cheung and Yiu (2007) describe a dispute as a disagreement over an issue related to project

¹ Undergraduate, Department of Building Economics, University of Moratuwa, Sri Lanka, oshadha1998hirushan@gmail.com

² Senior Lecturer, Department of Building Economics, University of Moratuwa, Sri Lanka, mabeynayake@uom.lk

³ Lecturer, Department of Building Economics, University of Moratuwa, Sri Lanka, isurii@uom.lk

⁴ Lecturer, Department of Building Economics, University of Moratuwa, Sri Lanka, isurue@uom.lk

operations, typically stemming from differences in the understanding of the situation between two or more parties. A substantial portion of construction projects, ranging from 10% to 30%, encounter significant disputes (Alaloul et al., 2017). Escalating construction disputes are associated with negative social consequences as well. Moreover, infrastructure development projects and government projects face disputes more frequently due to the high complexity (Min et al., 2018).

Understanding the root causes of disputes is crucial for completing construction projects on time and within budget while minimising conflicts (De Alwis et al., 2016; Viswanathan et al., 2020). Researchers discovered factors such as erroneous designs, harsh weather conditions, change orders, and additional work as frequent causes of construction disputes (Kisi et al., 2020). Arcadis reports (2014, 2015, 2016, 2017, 2018, 2019, 2020) further identified failures in managing and administering contracts, poorly drafted claims, errors in contract documents, inadequate design information, lack of understanding or non-compliance of contractual obligations, negligence in issuing interim decisions on time extensions and compensations as causes of construction disputes.

The literature identified two broad dispute resolution approaches i.e., (i) early resolution methods, and (ii) late resolution methods. However, construction disputes are unavoidable due to differing perceptions among project participants. Consequently, experts focus more on mitigating and resolving disputes (Cheung & Pang, 2014). Dispute Mitigation refers to the strategies and processes used to prevent, manage, and resolve disagreements or conflicts that arise in the CI (El-Adaway, 2008). The goal is to resolve conflicts efficiently, maintain professional relationships, and keep the project on track (Abotaleb, 2018). Importantly, the incorporation of digital technologies is acknowledged as an effective pathway to address the root causes and thereby mitigate construction disputes (Rugină, 2021).

Smart Contracts (SCs) are prime examples of digital technologies that offer a pioneering approach to digitise construction contracts. SCs are self-executing contracts with terms directly written into lines of code and stored using blockchain technology, providing transparency, security, and immutability (Allen et al., 2019). Thus, SCs closely align with conventional construction contracts yet enhance efficiency and effectiveness through automation and thereby mitigate disputes (Li & Kassem, 2021). Additionally, they provide transparent, traceable, and real-time updated construction contracts which improve project management and stakeholder collaboration (Rugină, 2021). Thus, incorporating SCs presents a proactive approach to mitigate disputes in construction contracts by ensuring faithful adherence to the parties' original contractual intentions.

However, the Sri Lankan CI is less immune to the disputes that arise during the project lifecycle (Selvarajha, 2019). Existing studies have explored the applicability, advantages, challenges, and implementation strategies of SCs in the Sri Lankan CI (Anuradha et al., 2023; Weerakoon & Chandanie, 2021). Despite the commendable research efforts that describe the problems and solutions to the application of new technologies in the Sri Lankan CI and the impact of these technologies still, there is a critical gap in using SCs to mitigate construction disputes. However, the potential of SCs in mitigating construction disputes is a crucial aspect to be widely investigated. Thus, this research aims to investigate the applications of SCs to mitigate disputes in the Sri Lankan CI.

2. LITERATURE REVIEW

2.1 CAUSES OF CONSTRUCTION DISPUTES

Causes of construction disputes have been identified by various researchers 1990s. Accordingly, Jahren and Dammeier (1990) categorised the causes as changes in project conditions, payment-related matters, time-related delays, bidding errors, and communication deficiencies. Focusing on the Middle Eastern region, Awwad et al. (2016) categorised causes of disputes into twelve sets, including administrative, contractual, and cultural. Similarly, Cheung and Pang (2014) identified five primary causes of disputes and numerous underlying causes, whereas Marzouk et al. (2011) identified 44 causes. Upon consolidating the various causes of disputes, this study refined a total of 27 causes of disputes and categorised them into five groups, including design-related, employer-related, contractor-related, contractual, and other factors as shown in Table 1.

Table 1: Causes of construction disputes

	Causes of disputes	Reference
Design-related	Time limitations in the design phase	[1], [3], [4], [5], [6], [7],[8]
	Poor design	[2], [9], [17]
	Inadequate or incomplete technical plans/specifications	[1], [18]
	Poor preparation and approval of drawings	[2], [10], [11], [12], [13], [14]
Employer-related	Material changes and approval during the construction phase	[2], [8], [10], [15], [16]
	The slowness of the Employer’s decision-making process	[3], [10], [23]
	Inadequate early planning of the project	[3], [10], [22], [23]
	Failure to make interim awards on extensions of time and compensation by the Employer	[1], [20], [21], [22], [23]
	Variations initiated by the Employer (additive/deductive)	[1], [24], [25], [26]
Contractor-related	Poor Financing by the Employer	[2], [10], [12], [19], [26]
	Low financing by the contractor during construction	[2], [10], [12], [14]
	Shortage and unproductive workers	[10], [19], [24], [28]
	Inadequate site investigation	[2], [11], [14]
	Poorly defined scope of work	[3], [7], [8], [10], [16], [19]
	Poor supervision and site management	[3], [10], [30],
Contract - related	Unsuitable leadership style of construction/project manager	[3], [4], [5], [10], [27], [28]
	Underestimation and incompetence of contractors	[1], [10], [23],
	Poorly written contracts	[5], [10], [12], [27], [30]
	Differing Site Conditions	[9], [18], [29]
	Contract Amendments	[1], [20], [21]
Other	Contradictory and inaccurate information in the contract documents	[1], [5], [16]
	Lack of communication and coordination between parties during construction	[1], [5], [9]
	Modifying legislation and regulations	[3], [5], [7] , [15] , [16]

Reference :- [1] - (Awwad et al., 2016) , [2] - (Zaneldin, 2006) , [3] - (AL Mousli & El-Sayegh, 2016) , [4] - (Arain et al., 2006) , [5] - (Arain & Assaf, 2007) , [6] - (Lopez & Love, 2012), [7] - (Love et al., 2011), [8] - (Love et al., 2014), [9] - (Gad et al., 2011), [10] - (Faridi & El-Sayegh, 2006), [11] -

Causes of disputes	Reference
	(Mehany & Grigg, 2015) , [12] - (Farooqui et al., 2014), [13] – (Jergeas, 2001), [14] - (Mishmish & El-Sayegh, 2018), [15] - (Al-Dubaisi, 2000), [16] - (Weshah et al., 2013), [17] - (Ng et al., 2007), [18] - (Pineda Jr et al., 2023), [19] - (Ling & Poh, 2008), [20] - (Brammah, 2013), [21] - (Iyer et al., 2008), [22] - (Bramble & Callahan, 2010), [23] - (Shabbab, 2016), [24] - (Keane et al., 2010), [25] - (Enshassi et al., 2010), [26] - (Al-Nuaimi et al., 2010), [27] - (El-Sayegh, 2008), [28] - (Elmualim & Gilder, 2014), [29] - (Hickson & Ellis, 2014), [30] - (Charehzehi et al., 2017)

Design-related disputes arise due to short deadlines for design submission, insufficient technical plans, material specifications changes, and disputes between designers and employers (Mohd et al., 2014). Employer-related disputes result from prolonged decision-making, insufficient early planning, and seeking project variations (Mishmish & El-Sayegh, 2018). Contractor-related disputes arise from insufficient funding, subpar productivity, inadequate site investigations, and inadequate supervision (Trangkanont et al., 2018). Contract-related disputes can arise from poorly drafted contracts, particularly when differing site conditions occur (Eastman, 2011; Mitropoulos & Howell, 2001).

Other disputes can arise from nation-specific laws and regulations, unsuitable weather, lack of coordination, and projects requiring permissions or approvals from municipalities or government bodies. According to De Alwis et al (2016) and Illankoon et al (2022) poorly written contracts, poorly defined scope of work and poor design were the most significant causes of disputes in Sri Lankan CI.

2.2 ROLE OF SMART CONTRACTS IN MITIGATING DISPUTES IN THE CONSTRUCTION INDUSTRY

SCs powered by blockchain technology are revolutionising the CI by reducing uncertainty and ensuring clear terms (Samarasinghe & Wood, 2021). These self-executing contracts with immutable records significantly reduce disputes by improving transparency, efficiency, and automation. Further, SCs provide a record of all agreements and transactions on the blockchain, eliminating misunderstandings or disagreements over contract terms (Ye et al., 2022). According to Li and Kassem (2021), SC used an automated payment process, transparency, supply chain management, streamlined claim management process and dispute management process and enhanced safety compliance as a dispute mitigation application. Automated payments are tied to specific milestones, removing subjectivity and disputes over delayed or withheld payments (Sigalov et al., 2021). This improves transparency by providing an immutable record of all transactions and project data. Dubai's One Museum Project is a great example of a consortium piloting SCs for automated payments and streamlined approvals (Al Barghuthi et al, 2019). Additionally, SCs eliminate intermediaries such as lawyers or brokers, reducing the likelihood of disputes caused by miscommunication or conflicting interpretations of contract terms (Ahmadisheykhsarmast & Sonmez, 2018). SCs act as automated referees, enforcing clear terms and linking payments to achieved milestones. This transparency combined with the ability to tie actions to real-time data on safety or quality can streamline communication, ensure everyone follows the agreed-upon rules, and minimise disagreements. Integration with IoT devices facilitates real-time updates and monitoring, which helps in immediate reporting and issue resolution (Borgia, 2014). Accordingly, SCs can be effectively used to mitigate disputes in the CI. However, SCs have not yet been extensively studied resulting in a research niche to be fulfilled.

3. METHODOLOGY

Identifying the causes of disputes and their relative importance requires quantitative data whereas investigating the applicability of SCs in the Sri Lankan context needs qualitative data. Accordingly, this research employed a mixed-method approach to accomplish the research aim. An explanatory design was followed as it was necessary to assess quantitative before qualitative data to comprehensively investigate the applications of SC technology to mitigate disputes in the Sri Lankan CI.

As the first step of the data collection, a questionnaire survey was conducted to collect the quantitative data. The questionnaire consisted of two sections where section A focused on the background information of respondents and section B focused on the causes of disputes in the CI. The questionnaire was disseminated among a group of 50 CI professionals who were selected through convenience sampling based on their experience in handling construction disputes. Accordingly, 34 completed responses were received, reporting a response rate of 68%. Collected data were statistically analysed through Mean Weighted Average (MWA) and Relative Importance Index (RII) (Equation 01). A 5-point Likert scale analysis was used to rank the responses of experts where; 1-Not impacted; 2-Less impacted; 3-Average; 4-impacted; 5-Strongly impacted. By considering both significance and severity, the RII scores greater than 0.750 were identified as having the most significant impact on disputes in the CI.

$$RII = \frac{5n5+4n4+3n3+2n2+1n1}{A*N} \quad (Eq. 01)$$

Where, n5=Number of respondents for strongly substantial; n4=Number of respondents for substantial; n3=Number of respondents for average; n2=Number of respondents for less substantial; n1=Number of respondents for not substantial; A=Highest average and N=Total number of respondents (n1+n2+n3+n4+n5)

The qualitative approach allows the collection of data from comparatively a lesser number of participants and analyses in-depth (Creswell, 2012). Thus, the survey was followed by expert interviews to collect qualitative data. In-depth interviews reflect interviewees’ perspectives based on their experiences and understanding. Semi-structured interviews, while being guided by a defined framework allow the researcher for situational questioning based on the responses. Thus, semi-structured interviews were conducted with six interviewees who were selected through purposive sampling, considering knowledge and experience in working with SCs. Table 2 presents the profiles of the interviewees together with the selection criteria.

Table 2: Interviewee profiles and selection criteria

Interviewee	Criteria							Accessibility
	Compulsory Qualifications		Additional Qualifications (at least two criteria must be satisfied)					
E1	At least 10 years of working experience in the CI	Knowledge and interest in SCs	Completed a post-graduate qualification related to claims management	Knowledge and interest in BIM	Knowledge and interest in Blockchain	Knowledge and interest in IoT	Knowledge in construction dispute mitigation	√

Interviewee	Criteria							Accessibility
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	At least 10 years of working experience in the CI	Knowledge and interest in SCs	Completed a post-graduate qualification related to claims management	Knowledge and interest in BIM	Knowledge and interest in Blockchain	Knowledge and interest in IoT	Knowledge in construction dispute mitigation	
E2	√	√		√	√		√	√
E3	√	√		√	√		√	√
E4	√	√		√	√	√	√	√
E5	√	√		√	√	√	√	√
E5	√	√		√	√	√	√	√
E6	√	√		√	√	√	√	√

Interviews were conducted through online platforms, i.e., Zoom and Microsoft Teams, and each spanned between 45 and 60 minutes. Interviewees were questioned under three major sections based on the prepared interview guidelines. In the first section, the interviewee’s background details were questioned. The second section focused on the applications of SC in the CI, whereas the third section focused on SC in mitigating construction disputes. Situational questions were raised to clarify and explore the details further. Collected data was analysed through manual content analysis, and conclusions were drawn.

4. RESEARCH FINDINGS AND DISCUSSION

4.1 ANALYSIS OF THE QUESTIONNAIRE SURVEY

The questionnaire survey was conducted to identify the causes of disputes in the Sri Lankan CI. Table 3 provides the characteristics of the respondents based on their employment.

Table 3: Respondents' profiles based on employment.

Employment	No. of Responses	Percentage
Consultant party	16	47%
Contractor party	15	44%
Employer party	3	9%

Accordingly, consultants comprised 47% of the respondents, followed by contractors at 44% and employers at 9%. This diverse representation of different perspectives provides a comprehensive understanding of dispute dynamics. Additionally, Figure 1 represents the respondents' level of experience.

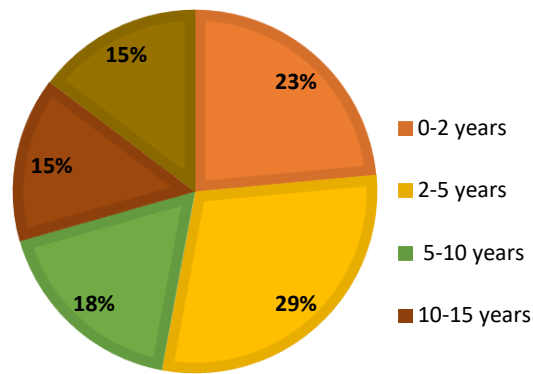


Figure 1: Respondents' level of experience

Results reflected that the survey employed respondents with varying levels of experience, with 66% falling within the two to ten years bracket and 15% having over 15 years of experience.

Upon collecting the background data, respondents were given a list of causes of construction disputes identified through the literature review and asked to measure the significance of each cause in the Sri Lankan context. As per the results of the questionnaire survey, the causes were ranked under the RII score. Table 4 presents the overall ranking of the causes of disputes along with the RII score.

Table 4: Ranking of the causes of disputes

Causes	RII	MWA	Rank
Poorly written contracts	0.827	4.198	1
Poor preparation and approval of drawings	0.809	3.923	2
Lack of communication and coordination between parties during construction	0.809	4.066	2
Poor supervision and site management	0.797	4.000	4
Contradictory and inaccurate information in the contract documents	0.786	3.923	5
Poorly defined scope of work	0.768	3.802	6
Poor design -Conflicts in construction drawings	0.762	3.758	7
Underestimation and incompetence of contractors	0.762	3.945	7
The slowness of the Employer's decision-making process	0.751	3.846	9
Unsuitable leadership style of construction/project manager	0.735	3.780	10
Inadequate or incomplete technical plans/specification	0.729	3.615	11
Variations initiated by the Employer (additive/deductive)	0.729	3.582	11
Poor Financing by the Employer	0.729	3.626	11
Inadequate site investigation	0.729	3.703	14
Inadequate early planning of the project	0.724	3.648	15

Causes	RII	MWA	Rank
Failure to make interim awards on extensions of time and compensation by the Employer	0.724	3.538	15
Material changes and approval during the construction phase	0.712	3.538	17
Differing site conditions	0.694	3.418	18
Modifying legislation and regulations	0.676	3.330	19
Shortage and unproductive workers	0.671	3.385	20
Low financing by the contractor during construction	0.647	3.176	21
Contract Amendments	0.647	3.121	21
Time limitations in the design phase	0.641	3.385	23

In a similar study, Abotaleb (2018) considered the causes with more than 0.750 RII scores as highly impacted causes of disputes. Accordingly, out of the 23 analysed causes, nine were in highly impacted category. Moreover, poorly written contracts were the most significant cause of dispute in the Sri Lankan CI. Further, the results highlighted the importance of unambiguous contractual agreements in preventing and resolving conflicts. The lack of effective communication and coordination between parties during construction is another impactful cause of disputes. Confirming the findings of Awwad et al. (2016), results revealed that design, planning, and decision-making challenges contribute to disputes, creating issues in the preparation and approval of drawings and technical plans and delays in decision-making. In support of Abrey and Smallwood (2014), contractual ambiguities and inconsistencies exacerbate disputes, emphasising the need for precise contractual frameworks. In favour of Mehany and Grigg (2015) operational and managerial challenges such as poor financing practices, inadequate site investigation, and poor workforce productivity fuel disputes. Thus, the findings underscore the need for robust financial planning, thorough site assessments, and diligent project oversight to address potential triggers of disputes before they escalate.

4.2 ANALYSIS OF THE EXPERT INTERVIEWS

Since the literature review primarily explored the causes of disputes in the CI and using SCs in dispute mitigation, the expert interviews aimed to study the application of SCs in the Sri Lankan context and its potential benefits in mitigating construction disputes.

4.2.1 Potential Applications of Smart Contracts in the Sri Lankan Construction Industry

Initially, the interviewees were questioned about the potential applications of SCs in the Sri Lankan CI. The literature revealed five potential SC applications in dispute mitigation. Thus, the interviewees were asked to comment on their suitability in the Sri Lankan context and to suggest any possible applications. Table 5 presents the findings.

Table 5: Application of SCs in the Sri Lankan CI

Applications of SCs in the Sri Lankan CI	E1	E2	E3	E4	E5	E6
Automated payment process	√	√	√	√	√	√
Enhanced transparency	√	√	√	√	√	√
Improved supply chain management	√	√	√	√	√	√

Applications of SCs in the Sri Lankan CI	E1	E2	E3	E4	E5	E6
Streamlined claim management process & dispute management process	√	√	√	√	√	√
Enhanced safety compliance	√	√	√	√	√	√
Quality Assurance (QA) & Quality Control (QC) procedure	√	√	√			√

Accordingly, all the experts confirmed the findings of the literature regarding the applications of SC to mitigate construction disputes. E1 additionally suggested the use of SCs in QA and QC procedures which was confirmed by E2, E3, and E6. Agreeing with Ahmadisheykhsarmast and Sonmez, (2020), all the interviewees discussed the benefits of SCs in the automated payment process highlighting the importance of accurate billing and informing contractors about completed tasks. Furthermore, E5 mentioned that “*after all updates happen the SC takes a look at the quantities of work that have been completed automatically calculated from the updated module. Then, based on those quantities, it processes the payment*”. Clarifying Sigalov et al. (2021), E1 and E3 highlighted the roles of blockchain and BIM integration in providing complete records of project progress and transactions, increasing accountability and trust among stakeholders. E4, E5, and E6 emphasised the immutability of SC data, enhancing transparency and minimising errors. Confirming the idea of Li and Kassem (2021) E5 claimed that “*transparency is very high in SCs as once something is stored or stated in the system, it cannot be changed*”.

Agreeing with Lu et al. (2021) E1, E2, E3, and E6 emphasised the importance of integrating construction programs with supply chain management systems to monitor activities effectively. SCs facilitate keeping projects on schedule and within budget by reducing costs and minimising delays. Moreover, E1 stated, “*SCs are used in QA and QC procedures by gathering real-time data on construction progress and quality and analysing it against predefined quality criteria.*” Accordingly, it refines the quality standards and processes for future projects, leading to continuous improvements in project quality and efficiency.

The application of SC can be used to mitigate construction disputes. SC are self-written programs based on clear terms. This removes ambiguity and ensures everyone involved is on the same page. Additionally, Smart Contracts (SCs) can link approved drawings to material orders and payments. If there is a discrepancy, the automated process can be halted, preventing issues and potential disputes. Apart from that all information about the project, including approvals, changes, and communication, is stored on a secure, shared ledger. This fosters better communication and reduces misunderstandings. Moreover, SC can be linked to sensors or monitoring systems that track safety protocols and quality control measures. If a breach occurs, the contract can automatically trigger corrective actions or halt work, preventing accidents and rework disputes

4.2.2 Benefits of using Smart Contracts in Mitigating Construction Disputes

According to E1, E4, E5 and E6, SCs automate several manual tasks in claim management, such as data collection, verification, and payment processing. This significantly reduces the administrative burden on contracting parties. E1 stated that “*traditional claim management involves a lot of paperwork, back-and-forth communication, and manual data processing. However, SCs automate many of these tasks*”. For instance, SCs trigger payments upon completion of specific milestones as

defined in the contract. Moreover, E1, E2 and E3 highlighted the SC's capability in document storing, document managing and communicating electronically, which allows automatic claim calculations and verification based on pre-defined criteria. SCs provide a transparent record of transactions and interactions between parties, fostering trust and reducing disputes by ensuring everyone clearly understands the contractual terms and obligations.

E1, E2, E4, and E6 highlighted the benefits of SCs in dispute resolution. SCs automate contract terms, release withheld funds, and trigger arbitration mechanisms, saving time and money compared to traditional litigation methods. E2, E3, and E5 highlighted the importance of a complete record of contract activity for accurate decision-making. SCs facilitate better communication and collaboration between parties by providing a shared platform for storing and accessing contract information. E4 highlighted the reduction in administrative costs associated with claim management and faster dispute resolution with minimal legal fees.

According to SC E1, E2, E4 and E6 based strategies offer innovative solutions to design-related disputes, such as using messaging or flagging systems within contracts to address ambiguities or discrepancies in drawings and integrating smart validation tools within BIM systems to automate checks for compliance and accuracy. This streamlines the drawing review and approval process, ensuring efficiency and consistency while minimising disputes. Additionally, SC-based strategies can assist engineers in making informed decisions more efficiently, leveraging advanced technologies and automation. These strategies aim to minimise delays and ensure smoother project execution in the construction industry.

5. CONCLUSIONS

This research provides valuable insights into the causes of construction disputes and the potential use of SCs to mitigate the disputes. Importantly, it contributes to filling a research gap in the technology-based dispute mitigation measures in the Sri Lankan context. The findings reveal that poorly written contracts, poor preparation and approval of drawings, and lack of communication and coordination between parties during construction are the most significant contributors to disputes in the Sri Lankan CI. Subsequently, the application of SCs presents a proactive approach to mitigate these disputes by ensuring faithful adherence to the parties' original contractual intentions. SCs enhance transparency, improve supply chain management, streamline claim and dispute management processes, and enhance safety compliance and QA QC procedures.

Furthermore, the research underscores the transformative potential of SCs in revolutionising the CI. By automating payment processes, enhancing transparency and traceability, facilitating efficient dispute resolution, improving communication and collaboration, enabling accurate decision-making, and enhancing value for money, SCs offer a promising solution to the perennial problem of construction disputes. However, the successful implementation of SCs requires a comprehensive understanding of their potential benefits and challenges, as well as a conducive regulatory and technological environment. Thus, future research could further explore the practical challenges and strategies for implementing SCs in the Sri Lankan CI.

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