ADVANCING CONSTRUCTION CONTRACT RISK MANAGEMENT THROUGH NLP: INSIGHTS, CHALLENGES, AND OPPORTUNITIES

Saad Rasool[1], Yuting Chen, Chika Udeaja and Daniel Fong

College of Technology and Environment, London South Bank University, London, United Kingdom, SE1 0AA, UK

Disputes in the construction industry are increasingly complex, making the need for robust construction contractual risk management (CCRM) more vital to improving project performance in terms of cost, time, and quality. Natural Language Processing (NLP) is found to be a promising solution for creating CCRM system. However, there is very limited research into the application of NLP to CCRM over the last two decades. This study aims at conducting a scientometric analysis by using VOS Viewer for summarising key trends, challenges, and opportunities in NLP applications for CCRM. The results of the study identify gaps in interpreting complex construction legal language, especially nuanced contractual clauses that current NLP is unable to understand correctly; these require well developed methods for NLP studies. Besides that, limited inter-disciplinary research is observed among several knowledge fields: construction, law, management and computer science, leading to shortcomings regarding the elaboration of multipurpose applications for managing the process of risks. The paper concludes that meeting these challenges will utilise NLP's full potential for transformation in the automation and enhancement of CCRM practices yielding better project outcomes.

Keywords: construction contract risk management; contracts; natural language processing; legal text analysis; scientometric analysis

INTRODUCTION

The CCRM is one of the key parameters in the project success. The contractual approach to risk management involves distributing risks among the involved parties within the contracts to facilitate efficient and effective management of these risks throughout the construction process (Zhang *et al.,* 2006). Construction projects, due to their unique characteristics, involve numerous interconnected activities fraught with risks, each capable of affecting costs, timelines, and quality to varying degrees. To ensure project success, a robust risk management system is essential, typically encompassing identification, analysis, and response (Burke, 2013). This enables stakeholders to effectively address risks as they arise. Moreover, manual construction contract risk review is tedious prone to errors and inefficiencies (Lee *et al.,* 2020).

[1] s4314229@lsbu.ac.uk

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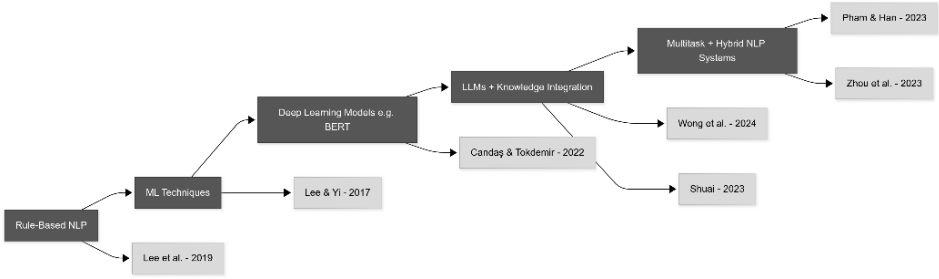
Natural Language Processing (NLP) is a promising solution for enhancing automation, accuracy, and adaptability in CCRM.

In recent times, as NLP has advanced and gained traction within the field of computer science, certain researchers have endeavoured to apply NLP techniques to the construction sector. The expanding use of artificial intelligence (AI), and more especially NLP, in CCRM is a major driving force behind this study. AI is a broad field, while NLP is a subfield focused on understanding and processing human language. Shamshiri *et al. (*2024) conducted a thorough review by aligning the objectives of 205 publications with various domains, areas, tasks, and processes in construction management practices. Through this review, they unveiled numerous facets of the construction sector bolstered by Text Mining (TM) and NLP approaches. Although the review covers certain aspects of risk management, a comprehensive scientometric analysis is warranted to pinpoint research gaps and identify emerging trends in this critical area of construction project management. Therefore, the aim of this study is to use scientometric techniques to examine research trends in NLP-driven contract risk management, emphasising the transition from rule-based systems to Machine Learning (ML), Deep Learning (DL), and Large Language Models (LLMs). The findings aim to inform future research directions that incorporate NLP tools into CCRM processes. It highlights significant developments, seminal publications, and potential paths forward for AI-driven contract analysis.

LITERATURE REVIEW

Scientometric analysis provides valuable insight into publication trends and thematic clusters, it is limited in offering deeper interpretive insights into the literature. To address this, the study includes a targeted review of high-impact articles within the identified clusters, providing a more nuanced understanding of emerging developments and practical challenges in CCRM. From rule-based approaches to sophisticated ML and DL techniques, NLP in contract analysis has advanced, facilitating effective risk identification, automated contract reviews, and decision-making in construction contract management. Although they relied on syntactic/semantic rule matching and lexicon-based NLP, early rule-based models, such as Lee *et al. (*2019), lacked flexibility. With research like Lee and Yi (2017) using classifiers like ANN, SVM, KNN, and NB for contract risk prediction, the rise of ML enhanced automation. As demonstrated by Moon *et al. (*2022a), who used BERT for risk categorisation, and Candaş and Tokdemir (2022), who created a vagueness detection system for FIDIC contracts, DL further improved contract analysis.

Figure 1: Evolution of CCRM using NLP



In recent years, Wong *et al. (*2024) and Shuai (2023) have shown how to link LLMs with domain-specific knowledge bases using knowledge- and rationale-augmented frameworks, which improve explainability and scalability. Further optimising

contract risk management, hybrid approaches like similarity-based clause identification (Zhou *et al.,* 2023) and multitask learning (Pham and Han, 2023) combine rule-based NLP, ML, and DL to improve efficiency, accuracy, and adaptability. The summary and the evolution of these recent studies on NLP in CCRM is presented in Table 1 and Figure 1. The selection of these studies is based on the evolution of NLP in CCRM over the years.

METHOD

To conduct a thorough scientometric evaluation, a tangible technique is essential in which a methodical approach is employed. The present study used a scientific mapping approach to create a bibliometric map of CCRM using natural language processing, based on sources from the Google Scholar and Scopus databases from 2015 to 2025.

Author(s)	Review Type	Review Method	Focus of Study
Lee and Yi (2017)	Empirical	TM and risk prediction	Bidding risk prediction (text and numerical)
Lee *et al.,* (2019)	NLP and Rule-based	Semantic analysis and rule-based extraction	Auto risk clause extraction
Candaş and Tokdemir (2022)	Supervised Learning	ML-based risk classification	Vagueness in FIDIC Silver Book
Shuai (2023)	NLP and AI	Rational-augmented NLP	Unilateral change risk (EPC)
Zhou *et al.,* (2023)	DL and NLP	BERT-based multi-label classification	Missing clause detection
Pham and Han (2023)	Multi-task NLP	Semantic classification	Semantic risk action prediction
Wong *et al.,* (2024)	NLP-Knowledgebase	Large Language Models	Knowledge-based risk ID

Table 1: Recent Studies on CCRM using NLP

A bibliometric search, a scientometric data analysis, and a thorough discussion of the study's findings are among the steps of the review structure and procedures depicted in Figure 2.

Figure 2: Overview of Methodology of Scientometric Review Study

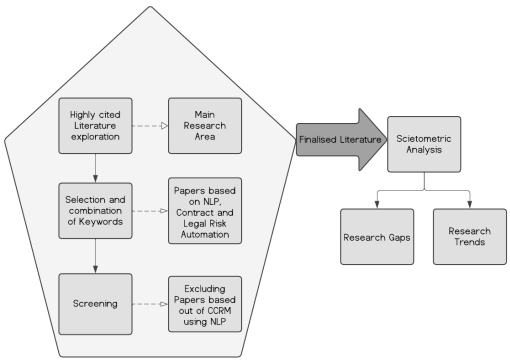


Figure 3: Most Used Keywords

Figure 3 shows the most often used terms and their combinations in the highly cited literature. Relevant papers are extracted using these keyword combinations from

Scopus and Google Scholar (GS). Any document having an academic structure was indexed by GS, which also discovered the highest percentage of citations. However, when two or more online versions of the same journal article are identified, this results in discrepancies and occasionally double citation counts, reporting larger citation counts than the fact (Derbe *et al.,* 2020). These could significantly affect citation metrics, leading to erratic outcomes. For more accurate and consistent results, journals that are indexed by Scopus are used in this study.

The manual evaluation of several research publications is time-consuming and prone to errors and inconsistencies. Therefore, scientometric data analysis is adopted for comprehensive review of bibliometric literatures. Due to its exceptional mining and visualisation capabilities for large amounts of textual data, VOSViewer, a scientometric analysis software program, was used to build and analyse the bibliometric network of science. To find influential researchers, publication papers, and journals, VOSViewer assisted to create, visualise, and analyse bibliometric networks; map and analyse research topic trends using bibliometric networks of words in the CCRM domain using NLP; and analyse 61 journal articles and conference papers with XLSX format file that was downloaded from Scopus (Derbe *et al.,* 2020).

FINDINGS AND DISCUSSION

The author(s) performed a thorough discussion based on scientometric analysis to summarise the main research themes, pinpoint research gaps, and establish a framework for future study. The following subsections provide illustrations of the specific findings and discussion.

A Synopsis of Bibliometric Research

Figure 4 displays the total number of articles published in the field of CCRM employing NLP between 2015 and 2025. This period captures the rise of CCRM as a distinct research area and the growing use of AI and NLP in construction. It reflects key developments in digital risk management and supports forward-looking trend analysis. Since the data was gathered up until March 6, 2025, the number of papers published for 2025 was not comprehensive. The graph, however, demonstrates a notable rise in publications starting in 2018 and peaks in recent years, suggesting a growing interest in the topic among researchers. This surge likely coincides with the wider adoption of AI and NLP technologies in construction.

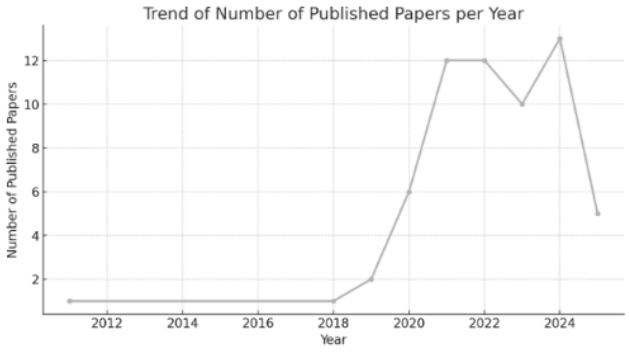


Figure 4: Trend Graph of Published Papers

Key Influential Journals

Figure 5 and Table 2 list the key influential journals in CCRM that use NLP. These prestigious journals were analysed and visualised using VOSViewer's 'citation-

documents' bibliometric network. A minimum of two research papers have been chosen for each journal. The number of publications, total citations, and total link strength, all of which indicate a source's level of connection within the research community are among the important metrics included in each entry.

Automation in Construction is the most influential journal among the sources examined, with eight papers, 222 citations, and the greatest total link strength of 441. This implies that it is a major topic of discussion in scholarly settings concerning construction automation. The Journal of Legal Affairs and Dispute Resolution in Engineering and Construction, with 127 citations, and the Journal of Computing in Civil Engineering, with 136 citations, are two other noteworthy sources. Research on the legal elements of engineering projects and computing in construction is greatly aided by these periodicals.

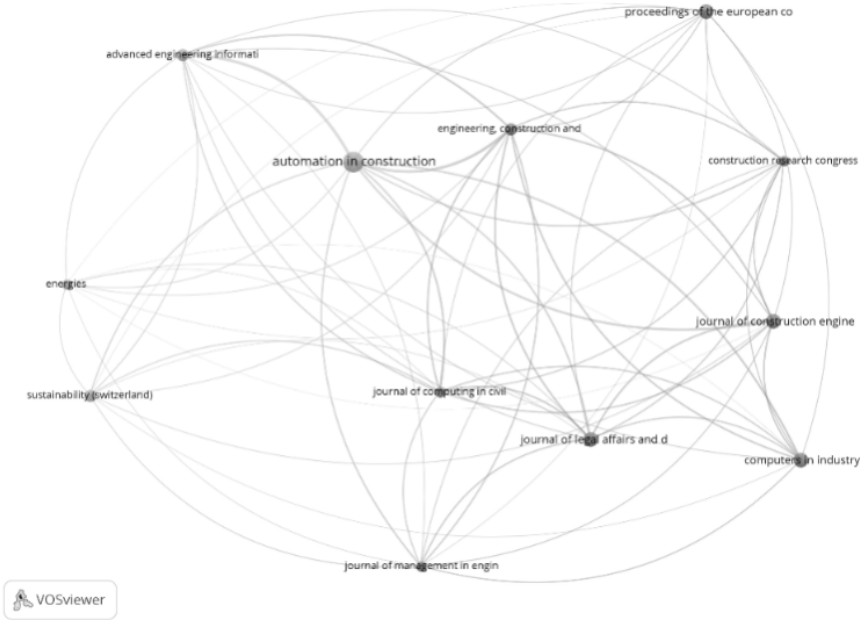


Figure 5: Bibliometric Network of Most Influential Journals

Source	Documents	Citations	Link Strength
Advanced Engineering Informatics	3	95	235
Automation in Construction	8	222	441
Computers in Industry	4	22	204
Construction Research Congress 2022: Project Management and Delivery, Controls, and Design and Materials	2	4	152
Energies	2	49	56
Engineering, Construction and Architectural Management	3	46	328
Journal of Computing in Civil Engineering	2	136	217
Journal of Construction Engineering and Management	4	99	239
Journal of Legal Affairs and Dispute Resolution in Engineering and Construction	4	127	220
Journal of Management in Engineering	2	79	150
Proceedings of the European Conference on Computing in Construction	4	2	90

Table 2: Most Influential Journals

Bibliometric Network of co-occurrence of keywords

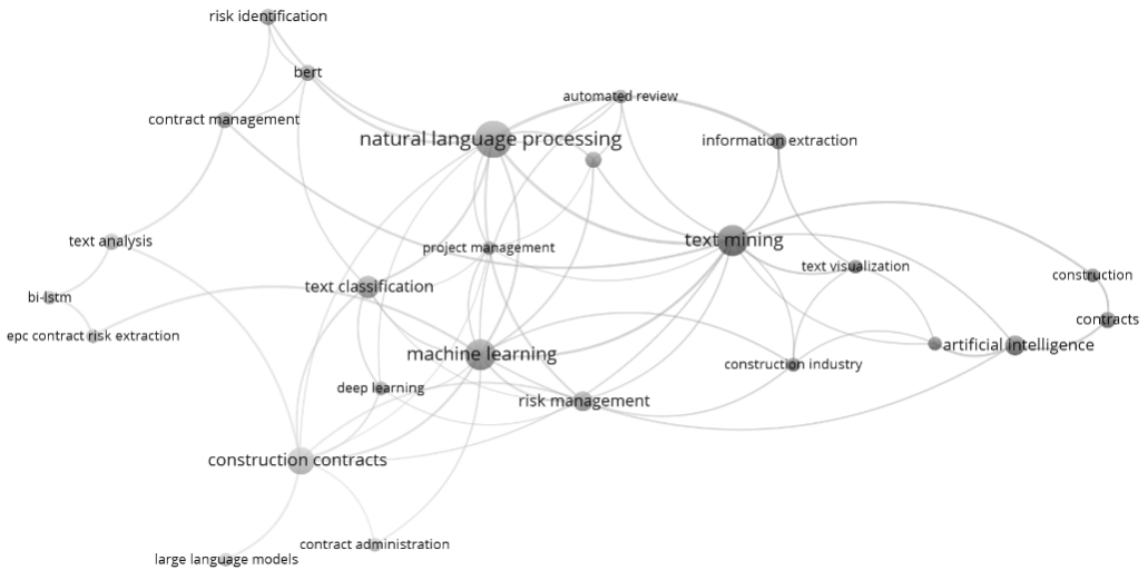
The bibliometric network's keywords show the primary themes of intellectual collaboration and organisations as well as the general boundaries of earlier study. The

following study has adopted bibliometric mapping of co-occurrence of terms using 'fractional counting' and 'author keywords' in VOSViewer to establish a bibliometric network. The major keywords had to appear at least twice. During the initial result, 177 keywords out of 30 keywords satisfied the criterion. Words with the same meaning but multiple differences, like construction contract versus construction contracts, were chosen with a higher occurrence value. Keywords with similar semantic connotations, like artificial intelligence (AI) versus artificial intelligence, and natural language processing (NLP) versus NLP, were disregarded. Twenty-five keywords in all were selected, as indicated in Table 3 and Figure 6. Based on co-occurrence in bibliographic data, link strength in VOSViewer measures the relationship between two elements, such as authors, keywords, or documents. For instance, in keyword co-occurrence analysis, two terms that have a connection strength of five appear together in five publications. These values aid in locating networks and clusters of interest for research.

Table 3: Co-occurrence of Keywords

Keywords	Occurrences	Link Strength	Keywords	Occurrences	Link Strength
Natural Language Processing	14	12.0	Risk Identification	3	2.0
Machine Learning	10	9.0	Text Analysis	3	3.0
Text Mining	10	10.0	Automated Review	2	2.0
Construction Contracts	8	7.0	Bi-LSTM	2	2.0
Text Classification	5	4.0	BIM	2	2.0
Artificial Intelligence	4	3.0	Construction	2	2.0
Risk Management	4	4.0	Construction Industry	2	2.0
BERT	3	3.0	Contract Administration	2	1.0
Construction Specification	3	3.0	Deep Learning	2	2.0
Contract Management	3	3.0	EPC Contract Risk Extraction	2	2.0
Contracts	3	2.0	Large Language Models	2	1.0
Information Extraction	3	3.0	Project Management	2	2.0
			Text Visualisation	2	2.0

Figure 6: Bibliometric Network of Co-occurrence of Keywords



The VOSViewer generated keyword co-occurrence network identifies important study areas at the nexus of TM, ML, AI, and construction contract analysis. NLP and risk identification are at the centre of a significant cluster, with research using models such

as BERT and Bi-LSTM to automate risk assessment and contract review. Scholars like Moon *et al. (*2022a) and Pham and Han (2023) have shown how NLP may be used to identify hazards in FIDIC and general construction contracts at the pre-bid stage. In a similar vein, the ML in Project and Risk Management cluster concentrates on using AI-powered predictive analytics to improve construction project risk reduction. To assist data-driven decision-making for contract compliance and risk monitoring, study by Siu *et al. (*2018) demonstrate how ML models are being used to assess risk registers and textual risk descriptions.

The development of AI-powered solutions for automated risk assessments and legal compliance checks is another noteworthy trend in TM and AI-based construction document analysis. Scholar such as Shuai (2023) have investigated TM methods to monitor contractual deviations and examine legal provisions in EPCs. Study by Candaş and Tokdemir (2022) demonstrate growing interest in blockchain-based smart contracts and AI-enhanced contract administration, which is reflected in the Smart Contracting and Legal Tech in Construction cluster. Finally, works Choi *et al. (*2021a) and Choi *et al. (*2021b) demonstrate ML applications in EPC and ITB contract risk classification, highlighting the critical role that text classification and risk extraction play in AI-driven contract analytics. When taken as a whole, these study clusters show that AI and ML are increasingly being used in contract management to improve risk assessment, compliance, and decision-making in building projects.

Citations of articles

Each of the research papers in the dataset with at least 30 citations is represented by the VOSViewer network visualisation. 13 documents in all satisfied this requirement, showcasing the most important contributions to this field of study, as seen in Table 4. It appears that research in this topic is fragmented, with influential papers being cited in various places rather than establishing a coherent citation network, as evidenced by the high citation counts of several articles despite poor linkages. Some study subfields are more interconnected than others, as evidenced by the existence of small, closely related clusters (e.g., Marzouk (2019) and related works), which may result in future research collaborations that are more robust. The increasing popularity of recent studies (Moon (2022a), Choi (2021b), etc.) suggests that the area is still developing and that new study subjects are appearing. This implies that to examine how these more recent papers fit into the larger body of research, future bibliometric studies must keep tabs on them.

Table 4: Citations of Articles

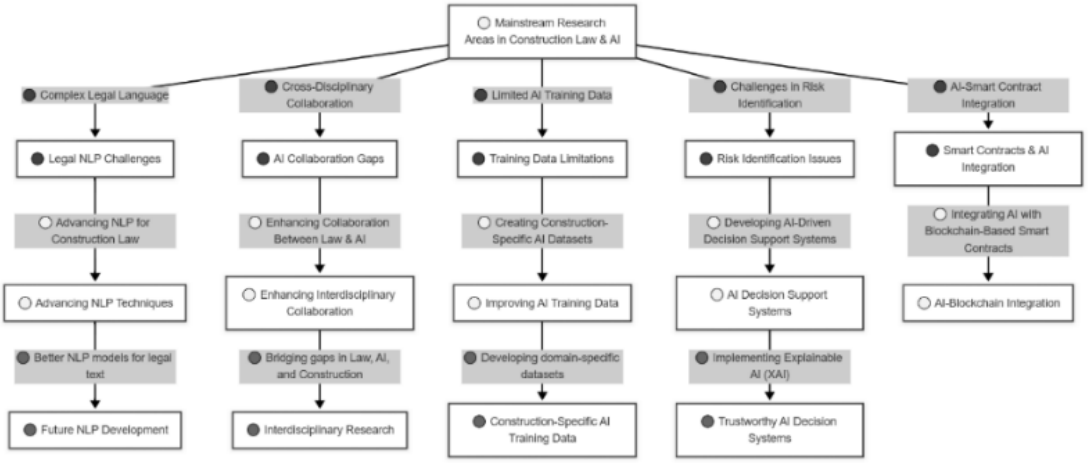
Document	Citations	Links	Document	Citations	Links
Lee (2019)	120	0	Xu (2021)	57	0
Hassan (2020)	96	0	Moon (2022a)	55	0
Marzouk (2019)	71	3	Sun (2020)	44	0
Moon (2021)	68	0	Choi (2021b)	41	0
Lee (2020)	62	1	Gurgun (2022)	39	0
Choi (2021a)	33	1	Moon (2022b)	34	1

DISCUSSION

Beyond identifying frequent keywords and citation patterns, the findings suggest that research in CCRM is increasingly focused on risk prediction models, AI integration,

and collaborative contracting. However, the dominance of citation metrics may obscure less cited but potentially transformative research. For example, while smart contract applications receive fewer citations, they represent a frontier in risk minimisation strategies. A thorough depiction of the primary study areas, gaps, and trends is provided in Figure 7. Given NLP's difficulty understanding complicated contractual agreements and duties, legal language complexity continues to be a significant obstacle. The accuracy of risk categorisation is weakened by a lack of annotated datasets, and customised NLP models are limited by the absence of multidisciplinary cooperation between law, NLP, and construction management. Additionally, unclear contract conditions make it challenging to automate risk identification, and there is still much to learn about integrating NLP with blockchain-based smart contracts for real-time compliance monitoring.

Figure 7: Mainstream Research Areas, Gaps and Trends



Future research should prioritise interdisciplinary methods that integrate data science with legal engineering to address contract ambiguity and automation, upgrading NLP methods with domain-specific LLMs, and enhancing decision support systems using Explainable AI (XAI). AI-driven contract management in construction will advance with the development of extensive construction contract datasets and the integration of AI with blockchain-based smart contracts, which can facilitate automated risk assessment and compliance monitoring. The main research areas in Construction, Law and AI are highlighted with following key enhancements: Main Research Areas (white circles), Gaps (red circles), and Trends (blue circles).

CONCLUSION

This study offers a scientometric assessment of CCRM using natural language processing (NLP), highlighting significant advancements, challenges, and future directions. NLP and ML help with contract analysis and risk assessment but working with legal jargon and integrating AI into contract management still pose challenges. Lack of cross-disciplinary research and annotated datasets limit the utility of artificial intelligence. Closing these gaps requires cooperation between domain-specific AI models and experts in AI, law, and building. Future developments in blockchain-integrated smart contracts, AI-driven decision support systems, and natural language processing could revolutionise contract risk management by reducing disputes.

Data Availability Statement

All data used for the scientometric analysis is available and accessible upon request.

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