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Theoretical and Practical Instantiations of Generative AI in Construction Risk Management: An Analytical Exposition of Its Latent Benefits and Inherent Risks

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Abstract

The construction industry's increasing complexity and dynamic project environments engender advanced risk management strategies. AI-based risk management tools, reliant on complex mathematical models, often impose specialised coding requirements, leading to challenges in accessibility and implementation. In this vein, Generative Artificial Intelligence (GenAI) emerges as a potentially transformative solution, leveraging adaptive algorithms capable of real-time data analysis to enhance predictive accuracy and decision-making efficacy within Construction Risk Management (CRM). However, integrating GenAI into CRM introduces significant challenges, including concerns around data security, privacy, regulatory compliance, and a skills gap. Our research seeks to address these issues by presenting a systematic bibliometric analysis that explores evolving trends, key research contributions, and critical methodological approaches related to GenAI in CRM. Thus far, our investigation has analysed 23 selected research articles from an initial corpus of 212 papers, spanning the period from 2014 to 2024. Early insights delineate a marked escalation in research activity from 2020 onwards, a surge likely engendered by

recent advancements in AI technologies and their applicability to construction management. We categorise GenAI's potential benefits into technical, operational, technological, and integration-related advantages, encompassing improvements in risk identification, predictive capabilities, scheduling, and cybersecurity. Simultaneously, we identify significant risks, particularly related to data governance, social acceptance, and the operational impacts of AI-driven decisions. These preliminary findings underscore the imperative for systematic governance frameworks and proactive stakeholder engagement to optimise GenAI's benefits whilst mitigating its latent risks.

Keywords: Generative AI, Construction Risk Management, Data Governance, Predictive Modelling, Bibliometric Analysis, AI Integration Challenges.

1. Introduction

The construction industry has increasingly recognised the requirement for advanced risk management strategies, driven by the complex and dynamic nature of projects in general (Al-Mhdawi et al., 2022; Chenya et al., 2022; Corbin et al., 2024; Dong et al., 2024; Manh et al., 2024). Current AI-based risk management and predictive project data analytics are often imbued with complex requirements, relying on mathematical models that impose specialised coding expertise (Addo et al., 2020; Brookes et al., 2020; Hsu et al., 2021a; Hsu et al., 2021b). This reliance engenders additional complexities wherein project managers may revert to intuition rather than engaging in structured analysis (Al-Mhdawi et al., 2023; Ball and Watt, 2013; Dacre, Eggleton, Cantone, et al., 2021; Dacre, Eggleton, Gkogkidis, et al., 2021; Thomas et al., 2014). As such, the prevalence of subjective judgement introduces latent ambiguity and bias, thereby negatively affecting the precision and efficacy of risk assessments (Al-Mhdawi et al., 2024; Barber et al., 2021; Cox, 2008; Dacre, 2024).

In this vein, Generative Artificial Intelligence (GenAI) has emerged as a potential paradigm shift, employing adaptive algorithms capable of real-time analysis of extensive datasets (Dacre & Kockum, 2022a; Dacre et al., 2020; Dacre et al., 2024; Mandapuram et al., 2018). Our study seeks to delineate how GenAI's evolving models might enhance predictive accuracy and adaptability, thus offering insights crucial for mitigating risks such as cost overruns, delays, safety concerns, and resource allocation challenges (Eggleton et al., 2021, 2023; Ghimire et al., 2023; Mohammed and Skibniewski, 2023; Regona et al.,

2022). Unlike traditional AI models (Dacre & Kockum, 2022a; Dacre et al., 2019; Kockum & Dacre, 2021), which remain relatively immutable, GenAI's capacity for continuous refinement and adaptation underscores its potential to transform Construction Risk Management (CRM) (Dacre & Kockum, 2022b; Yan et al., 2024).

Conversely, the integration of GenAI in CRM is laden with significant barriers, including concerns around data security, privacy, regulatory compliance, and a pervasive skills gap (Baxter et al., 2023; Gupta et al., 2023; Osmeni and Ali, 2023; Schneider et al., 2024). The extensive use of sensitive data requires stringent governance frameworks and adherence to regulatory standards, which often lag behind technological developments, thereby creating a critical lacuna (Adekunle et al., 2022; Atkinson and Morrison, 2024; Dong et al., 2022; Gong et al., 2022; Parveen, 2018). Thus, addressing these challenges remains crucial to harnessing GenAI's full potential whilst ensuring ethical and compliant practices (Dacre et al., 2024; Pillai and Matus, 2020).

Hitherto, there has been an urgent need for empirical clarity concerning GenAI's dual impact, its capacity to transform risk management alongside the inherent risks it poses (Chenya et al., 2022; Jallow et al., 2023). This research aims to bridge these gaps by offering a bibliometric analysis, systematically examining extant academic discourse (Akinlolu et al., 2022; Guray and Kismet, 2023). This approach enables us to map key research trends, underscore thematic areas, and highlight both the benefits and ongoing challenges within CRM. Our specific research questions aim to investigate the annual publication trend on GenAI's benefits and risks in CRM between 2014 and 2024, identify the most influential journals, papers, and authors within this corpus, explore the methods most commonly employed to study these benefits and risks, and determine the categories of benefits and risks most frequently identified.

Addressing these questions allows our research to extrapolate a comprehensive overview of the current state of research (Reynolds & Dacre, 2019), thereby providing a heuristic framework that guides future efforts in optimising GenAI applications within construction risk management (Aria and Cuccurullo, 2017; Cobo et al., 2011; Waltman, 2016).

2. Systematic Research Approach

Our research will adopt a structured, three-step approach for literature collection and analysis, drawing inspiration from the methodology employed by Al-Mhdawi (2022). This approach facilitates a systematic and comprehensive examination of extant research, aiming to delineate key categories, benefits, and risks associated with GenAI in CRM. In order to achieve this, our methodology encompasses three sequential stages: database and journal identification, strategic article selection based on keywords, and a systematic content analysis (Hsieh & Barman et al., 2021).

2.1 Step One: Database and Journal Identification

We have selected multiple databases, including the ASCE Library, Emerald Insight, Google Scholar, IEEE Xplore, ScienceDirect, Scopus, Springer, Taylor & Francis, and Web of Science, in dint of their extensive coverage of construction management research (Blomkvist, 2015). These databases have been chosen to underpin our inquiry into academic works of high quality. Specifically, we will prioritise journals published in English with an impact factor of at least 1.0 and those that are situated within the top quartile of Scopus rankings. Nonetheless, we recognise the importance of key instantiations of research and, as such, may include seminal works, such as highly relevant papers from the European Safety and Reliability Conference, even if they fall outside these parameters (Ahuvia, 2001).

2.2 Step Two: Keyword Identification and Article Selection

Our strategy involves an exhaustive search in Scopus using title, abstract, and keyword (T/A/K) fields, employing terms such as “GenAI risks” “GenAI challenges” “GenAI benefits” “GenAI in CRM” and “GenAI in construction project management” (Al-Mhdawi, 2022). Articles that align with these criteria will be shortlisted for subsequent analysis. In order to ensure a holistic and pervasive understanding of the literature, we will replicate this search across the aforementioned databases: ASCE Library, Emerald Insight, Google Scholar, IEEE Xplore, ScienceDirect, Springer, Taylor & Francis, and Web of Science (Hsieh & Barman et al., 2021). This comprehensive search will allow us to address any potential lacuna in our dataset, thereby enhancing the robustness of our findings. Additionally, we will consider articles that explore GenAI model development pertinent to

CRM, especially those discussing management processes that impact risk assessment and mitigation (Blomkvist, 2015).

2.3 Step Three: Content Analysis

We intend to employ a conventional content analysis framework as outlined by Hsieh and Barman et al. (2021), which facilitates the emergence of themes and categories in a manner unencumbered by preconceived structures (Blomkvist, 2015). This analytical method enables both qualitative and quantitative engagement, integrating nuanced approaches such as reception-based and interpretive content analysis (Ahuvia, 2001). Our analysis will focus on extrapolating salient benefit and risk categories associated with GenAI in CRM, carefully evaluating the relevance of these studies to our overarching research objectives (Al-Mhdawi, 2024).

3. Initial Results

So far, we have examined 23 selected research articles published between 2014 and 2024, narrowed from an ongoing pool of currently 212 papers. The goal is to focus specifically on studies addressing the benefits and risks of GenAI within the CRM context. As such, initial insights from our analysis underscore a marked surge in research activity beginning in 2020, with a large number of pertinent studies published between 2020 and 2024. This escalation, particularly acute in 2023, suggests a pervasive academic interest in the ramifications of GenAI for CRM, likely engendered by rapid advancements in AI technologies and their complex applications in the construction sector.

Building on this observation, our citation analysis reveals that *Automation in Construction* stands as the most influential journal, displaying the highest publication and citation counts. Other significant journals, such as *Sustainability* and the *Journal of Computing in Civil Engineering*, have also emerged as pivotal in this research area. Influential papers, including those by Pan and Zhang (2021) and Abioye et al. (2021), are imbued with significant impact, as demonstrated by high normalised citation counts, which underscore their foundational roles in the extant research discourse.

Our keyword analysis further enriches this understanding, revealing terms such as “artificial intelligence” “project management” and “construction industry” as the most frequently occurring terms. The pervasive connection of these keywords highlights

emergent themes and reflects an integrated approach towards leveraging AI technologies for enhanced risk management. This evolving focus illustrates a coalescence of AI advancements with the inherent challenges of construction project management.

In parallel, our bibliographic coupling analysis indicates relationships between journals based on shared references, uncovering thematic clusters and scholarly networks. This mapping highlights a distribution and network of research knowledge, with key journals serving as academic hubs that foster scholarly collaboration. Such network analysis enhances our understanding of the modalities through which research trends and ideas may be disseminated.

Moving from publication patterns to research methodologies, our assessment of research methodologies reveals a predominant reliance on single-method approaches, with literature reviews constituting a majority of the studies. GenAI model training and testing represent the second most frequent methods, followed by expert interviews. This emphasis on efficiency, whilst practical, may engender limitations in the depth and granularity of insights gained into the identification of risks and benefits.

Our categorisation of GenAI's benefits in CRM suggests four main areas, technical, operational, technological, and integration-related advantages. Technical benefits, such as improved risk identification and predictive capabilities, emerged as the most salient, followed by operational benefits, which include enhanced scheduling and cost management. Technological advantages were often associated with automation and cybersecurity enhancements. Conversely, integration benefits, although less frequently cited, underscore the potential for transformative advancements through technologies like Building Information Modelling (BIM) and blockchain.

Conversely, on the risk spectrum, data-related challenges emerged as the most salient, with concerns about data quality, availability, and management critical for the successful deployment of GenAI. Social risks, encompassing issues of trust and transparency, were similarly pervasive, impacting the acceptance and efficacy of GenAI applications. Security risks, such as potential data breaches and cyberattacks, remain an endemic concern despite being mentioned less often. Resource and efficiency risks accentuate the necessity of

robust infrastructure and model performance, whilst operational risks highlight the potential deleterious effects of AI-driven decisions on project timelines and costs.

4. Discussion

Our initial findings reveal a surge in research on GenAI for CRM from 2020 to 2024, reflecting the sector's increasing openness to digital innovation (Al-Mhdawi et al., 2022; Regona et al., 2022). However, this rapid proliferation of studies raises critical questions about the maturity and long-term sustainability of GenAI adoption. While the influx of research suggests a high level of academic and industry enthusiasm, it also prompts concerns about the depth and quality of these studies (Pan and Zhang, 2021; Poh et al., 2018). For instance, the dominance of *Automation in Construction* illustrates a focus on automation and efficiency (Davahli et al., 2021). While this reflects the sector's pragmatic need to resolve longstanding inefficiencies, it may also indicate a lack of diversification in research perspectives (Erfani and Cui, 2022).

The initial keyword analysis also suggests a predictable focus on terms such as "artificial intelligence" and "project management," signalling a strategic emphasis on operational efficiencies (Yigitcanlar et al., 2022). However, the evolving inclusion of terms related to ethics and social concerns points to growing tensions concerning the broader implications of GenAI (Chenya et al., 2022; Holzmann and Lechiara, 2022). This shift is noteworthy but raises critical questions about whether the industry is prepared to address these challenges (Muller et al., 2024). For example, the construction sector, historically slow to adapt, may find itself ill-equipped to manage the ethical and socio-economic disruptions that GenAI could introduce (Pillai and Matus, 2020; Regona et al., 2022).

Our ongoing thematic clusters indicate a scattered approach, with research efforts converging around isolated ideas rather than a cohesive, strategic vision (Anysz et al., 2021; Boughaba and Bouabaz, 2020). This fragmentation not only complicates the translation of academic insights into actionable strategies but also suggests a discipline grappling with its own identity and direction (Jallow et al., 2023). Furthermore, the concentration of research output among a small group of influential authors and institutions underscores a homogeneity, which may limit the scope of inquiry (Lee et al., 2023; Zhao, 2024). The scarcity of multi-method studies also suggests a gap in evidence-based research, leaving practitioners with theoretical insights that may lack practical application

(Choi et al., 2021; Tang and Golparvar, 2021). This methodological limitation raises questions, especially given the high stakes of implementing AI technologies in complex construction environments (Pham and Han, 2023).

Our categorisation of benefits and risks presents a dual narrative. While GenAI offers significant technical and operational advantages (Afzal et al., 2021; Jallow et al., 2023), the prominence of data-related risks should not be minimised (Holzmann and Lechiara, 2022; Obiuto et al., 2024). Without effective data governance frameworks, the promise of enhanced risk management may remain unrealised, or worse, introduce new vulnerabilities (Gupta et al., 2023). Social risks, including trust and resistance to change, further complicate the research and practice landscape (Pillai et al., 2020; Regona et al., 2022). These human-centric challenges highlight a manifest oversight in current research and practice (Dacre, Yan, Frei, et al., 2024; Dong, 2023; Tite et al., 2021b), wherein the lack of focus on stakeholder engagement and change management strategies persists (Adekunle et al., 2022; Sonjit et al., 2021; Zhao, 2024).

5. Conclusion

Our ongoing research into the use of GenAI in CRM has delineated several emergent trends and critical considerations. The pronounced increase in academic publications from 2020 to 2024 underscores a growing recognition of GenAI's significance within construction engineering and management (Al-Mhdawi et al., 2022; Regona et al., 2022). This surge, coupled with a globally distributed research landscape, highlights a salient opportunity for international collaboration and cross-cultural knowledge exchange, an area that warrants further exploration as we expand our review of papers (Yigitcanlar et al., 2022; Zhao, 2024).

Our initial categorisation of GenAI benefits into technical, operational, technological, and integration-related aspects illustrates a broad spectrum of improvements GenAI can engender within CRM (Anysz et al., 2021; Dacre, AlJaloudi, et al., 2024; Dong et al., 2021; Jallow et al., 2023; Pan and Zhang, 2021; Pontin & Dacre, 2024; Tite et al., 2021a). Technical benefits, such as enhanced predictive capabilities, coalesce with operational efficiencies and technological advancements (Chenya et al., 2022; Poh et al., 2018). Conversely, the associated risks, particularly those concerning data quality, security, and social acceptance, underscore the imperative for effective mitigation strategies (Adekunle

et al., 2022; Holzmann and Lechiara, 2022; Obiuto et al., 2024). In this vein, future research should prioritise optimising risk-response strategies and proffering practical tools to leverage GenAI's potential whilst managing its inherent complexities (Pillai and Matus, 2020).

Ultimately, our research strives to balance the enthusiasm for GenAI's transformative potential with a critical awareness of its latent challenges, ensuring that adoption strategies remain both innovative and responsible (Muller et al., 2024; Regona et al., 2022). We anticipate contributing to a richer understanding of GenAI integration in CRM, offering insights that are as forward-thinking as they are rooted in practical realities (Tang and Golparvar, 2021). Thus, through our ongoing efforts we aspire to pave the way for a discourse imbued with both analytical depth and actionable relevance, fostering the effective and ethical application of GenAI within the construction industry.

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