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Unraveling the origins of construction rework: a holistic bibliometric analysis and exploration of causative factors

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Abstract

Purpose – Construction experts acknowledge the adverse effects of rework on project performance. However, the limited understanding of its underlying causes remains a significant challenge. Therefore, this study aimed to thoroughly investigate the sources of construction rework.

Design/methodology/approach – A mixed review using bibliometric analysis as a quantitative method and content analysis as a qualitative method was performed to understand the current knowledge in the field. The Web of Science (WoS) was selected for its comprehensive collection of major research articles and integrated analytical tools for generating representative data. The study involved an extensive bibliometric analysis of 107 journal articles on rework causes from 1991 to 2023. RStudio Bibliometrix, an R statistical programming package, was used to analyze rework origins. This method involved mapping the research landscape, identifying research gaps and analyzing emerging trends.

Findings – The causes of rework can be classified into three main clusters: human- and contractual-based rework causes, design-, quality- and project management-based rework causes and organizational-based rework causes.

Originality/value – Although several studies have addressed rework causes from various perspectives and methods, the topic has not been investigated holistically. This study is the first to leverage the quantitative and qualitative analytical capabilities of the RStudio Bibliometrix package. Innovative approaches, including the use of metrics, such as the h-index, thematic mapping and trend topic analysis, were employed for a comprehensive understanding of rework causes.

Keywords Rework, Causative factors, RStudio, Bibliometric analysis, Construction industry

Paper type Research paper

1. Introduction

The construction industry faces a substantial risk associated with rework, where performance undergoes scrutiny and criticisms regarding project outcomes are common (Janipha *et al.*, 2015). Project performance is primarily influenced by various elements, such as cost (Han *et al.*, 2013; Love and Sing, 2013), schedule (Han *et al.*, 2013; Hwang *et al.*, 2014), quality (Arain and Pheng, 2006), productivity (Arashpour *et al.*, 2014) and safety issues (Pereira *et al.*, 2020). The effects of these elements have been extensively studied (Hwang *et al.*, 2014). Scholarly works acknowledge that exceeding costs and timeframes, along with a decline in project performance, can be attributed to diverse factors, with rectification being a significant contributor (Hwang *et al.*, 2009; Love *et al.*, 2010). One of the significant factors affecting project performance is construction rework (Asadi *et al.*, 2023a, b).

Love and Smith (2018) outlined that rework involves the revision or repetition of tasks, resulting in inefficiencies and interruptions. Within the construction domain, rework is

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commonly defined as a non-value-adding activity, encompassing error corrections and defect rectifications, scope changes and noncompliance resolutions (Love *et al.*, 2016). Consequently, rework may involve task reassembly, tighter schedules, waste and loss of value (Kakitahi *et al.*, 2013). Kakitahi *et al.* (2016) estimated that rework affects project costs and schedules by approximately 4.53 and 8.42%, respectively. Josephson *et al.* (2002) conducted a survey through case studies, revealing that rework costs accounted for 4.4% of the construction value and consumed 7.1% of the total work time. Additionally, rework significantly contributes to reduced profits, increased claims and dissatisfaction among owners and contractors (Eze *et al.*, 2018).

In addition, rework can lead to labor and productivity inefficiencies. Thomas and Napolitan (1995) reported that daily labor productivity could suffer 25–50% losses owing to necessary alterations, primarily attributed to the unavailability of materials required for rework.

Construction professionals widely acknowledge the significant contribution of rework to the underperformance of construction projects (Love and Edwards, 2004). Thus, identifying rework origins is crucial for preventing its escalation to substantial management challenges (Hwang *et al.*, 2009; Ye *et al.*, 2015). Various research endeavors have focused on uncovering rework causes and the impact of rework on project costs and time in different construction industries and countries. Rework remains a significant global concern in the construction industry, evidenced by studies across multiple nations and sectors (e.g. Enshassi *et al.*, 2017; Mahamid, 2016). Scholars from developed countries, such as Australia (Love *et al.*, 2016; Love and Sing, 2013), the USA (Safapour and Kermanshachi, 2019) and the UK (Shahparvari, 2022) have made significant advancements in understanding rework causes. Researchers from developing countries, such as China (Liu *et al.*, 2020b; Ma *et al.*, 2019; Ye *et al.*, 2015; Zhang *et al.*, 2021), New Zealand (Asadi *et al.*, 2023a) and Spain (Forcada *et al.*, 2017), Uganda (Kakitahi *et al.*, 2016), Malaysia (Janipha *et al.*, 2015; Yap *et al.*, 2020; Yap and Skitmore, 2018), Palestine (Enshassi *et al.*, 2017), Indonesia (Alwi *et al.*, 1999) and Ukraine (Trach *et al.*, 2019), where construction is a pivotal economic activity, have demonstrated increasing interest in investigating rework causes. Furthermore, Ye *et al.* (2015) emphasized the scarcity of knowledge on rework causes in developing countries.

Previous studies on construction rework primarily focused on individual countries, offering valuable contributions but leaving a critical gap in providing a comprehensive and holistic understanding of rework causes on a global scale. Unlike previous studies that examined rework causes through traditional means, this study conducted a mixed review using interdisciplinary bibliometric and content analyses.

This study can revolutionize the understanding of rework causes by leveraging bibliometric analysis, a methodology not previously explored for identifying construction rework origins. This approach enables a more extensive and profound investigation of the subject matter, transcending geographical boundaries and disciplinary limitations. It offers a unique opportunity to gather data from diverse sources, potentially revealing intricate patterns and connections that traditional methods may overlook.

Bibliometrics plays a crucial role in understanding the advancement of academic disciplines and their potential trajectories. It provides insights into the historical evolution of a field by examining publication trends, citations and collaborative networks. It illuminates fundamental work, traces influential scholars and explains the interdisciplinary nature of the research. Using bibliometric analysis to understand field development offers a historical perspective and establishes the foundation for predicting future directions. Identifying emerging trends and knowledge gaps provides valuable insights for shaping future research priorities and fostering innovative avenues. This predictive ability supports stakeholders, policymakers and practitioners in optimizing resource allocation and steering research toward impactful directions.

This novel methodology shows potential for elucidating previously unexplored dimensions of construction rework causes. The interdisciplinary nature and utilization of bibliometrics provide a more detailed and comprehensive understanding of the factors influencing rework in construction projects. Therefore, the innovative approach of this study directly fills a gap in the literature by offering a novel perspective and methodology for comprehensively exploring the origins of construction rework.

This innovative approach differs from those of previous studies on construction rework. First, this is the first bibliometric study to comprehensively analyze articles related to construction rework published between 1991 and 2023. Second, it pioneers using quantitative and qualitative analyses (bibliometric and content analyses, respectively) for comprehensively reviewing construction rework causes. The quantitative facet offers numerical patterns and statistical evidence, while the qualitative analysis enriches our exploration with depth and nuanced insights. This approach mitigates the impact of subjectivity and biases commonly encountered in traditional review-based studies (Song *et al.*, 2016).

The research objectives include an extensive review covering temporal and geographical distribution, journal landscape, citation patterns, author contributions, keyword prominence and co-citation relationships related to rework cause research. In addition, this study explores the core research themes prevalent in this domain. Finally, this study identifies existing research gaps and establishes a framework to guide future research directions.

2. Existing studies on rework causes and literature gap

Numerous studies have identified the causes of construction rework, aiming to mitigate the adverse effects of rework on the construction industry. Several studies have uncovered factors related to construction rework including rework and labor productivity (Mahamid, 2020); safety performance (Yap *et al.*, 2020); supply chain (Love *et al.*, 2005a; Taggart *et al.*, 2014); schedule performance (Hegazy *et al.*, 2011; Hwang and Yang, 2014); design changes (Aslam *et al.*, 2019; Shoar *et al.*, 2022; Shoar and Chileshe, 2021); productivity (Arashpour *et al.*, 2014); project cost (Balouchi *et al.*, 2019; Liu *et al.*, 2020b; Love and Edwards, 2005); project and project performance (Al-Janabi *et al.*, 2020; Chidiebere and Ebhohimen, 2018; Enshassi *et al.*, 2017); material waste generation (Mahamid, 2022); organizational culture (Oyewobi *et al.*, 2016); and rework management (Zhang *et al.*, 2021). Additionally, relationships between reworks and contractual claims and contract documentation have been investigated (Asadi *et al.*, 2022, 2023a; Love *et al.*, 2005b).

The causes of rework in the construction industry have been investigated in the context of both developed and developing countries.

When the studies conducted in developed countries are analyzed; Safapour and Kermanshachi (2019) explored early indicators of manageable rework causes with a case study in the USA. Shahparvari (2022) highlighted the contribution of subcontractors to reworks in UK and revealed four root causes of rework regarding subcontractors. Love *et al.* (2010) identified 42 distinct factors to understand the fundamental reasons for rework and the associated financial implications in civil infrastructure projects in Australia.

The subject has attracted the attention of researchers in the construction industries of developing countries. Ye *et al.* (2015) conducted a survey in China to uncover the rework causes in construction projects and identified 39 causes classified into 11 major categories. Their findings revealed issues such as project management process ambiguity, subpar construction technology quality and the use of low-quality materials as the major rework causes. A survey conducted in Qatar by Jarkas (2015) identified 36 distinct rework causes in building projects, classified into four categories encompassing aspects related to clients, designers, contractors and external factors. Hwang *et al.* (2014) investigated client-related rework in building projects in Singapore using data collected from 51 construction

companies. They identified seven client-related factors as the root causes of rework. Enshassi *et al.* (2017) conducted a study on the Gaza Strip to examine rework causes in the construction industry. They identified a comprehensive set of 57 factors contributing to construction rework, categorized into seven distinct groups encompassing considerations related to the contractor, human resource capability, design, external environment, client, material and equipment supply and construction process. Eze *et al.* (2018) explored the rework causes in Nigeria's construction industry and identified 47 contributing factors categorized into four major groups.

While previous research have been valuable, they have primarily focused on either quantitative or qualitative examinations using methods, such as questionnaire forms, case studies, interviews, or system dynamics. Review studies are gaining substantial attention because they provide a holistic understanding. To comprehensively explore the foundations of rework research, researchers must adopt diverse perspectives and leverage existing knowledge. This provides an accurate representation of the research landscape, aiding scholars in understanding the status and future directions of rework-related challenges.

According to Pickering and Byrne (2014), a crucial initial step for researchers venturing into a new field is conducting a comprehensive literature search. Systematic literature reviews (SLRs) and bibliometric analyses are essential tools for guiding emerging researchers. Grant and Booth (2009) emphasized the significance of systematically synthesized summaries for helping researchers make informed decisions in their investigations.

An analysis of the relevant literature revealed that few studies used literature reviews and bibliometric analysis has not been employed in the rework domain (Table 1). Despite the availability of various approaches for conducting review studies (qualitative, quantitative and mixed reviews) (Creswell, 2014), qualitative methods were used in all previous rework review studies (Table 1).

Table 1 presents an overview of the review studies on rework causes, highlighting their contributions. Within this scope, Asadi *et al.* (2021a) comprehensively reviewed 280 documents published from 1990 to 2020 and identified rework causes originating from construction contracts through content analysis. Asadi *et al.* (2021b) reviewed 157 documents related to the common rework causes in construction contracts through content analysis, Subsequently, they explored construction contract issues using a quantitative survey. Safapour *et al.* (2022) reviewed 121 articles relevant to construction rework, weighted using the rank-sum method. Asadi *et al.* (2023a, b) critically reviewed 157 studies and classified them using Microsoft Excel. Although previous qualitative review studies offer valuable insights, their reliance on subjective and qualitative assessments limit their ability to provide a comprehensive and accurate depiction of the complex knowledge framework in rework cause investigations.

To leverage prior qualitative reviews in the research domain, scholars have gradually turned to quantitative review methodologies, such as meta-analysis, bibliometric analysis (Shi *et al.*, 2020) and/or mixed review methodologies (Hurol, 2020). Notably, no quantitative reviews or mixed-approach review studies have been conducted in the construction rework domain, limiting the availability of in-depth insights into rework origins.

Conducting a comprehensive bibliometric analysis using mixed review methodologies is crucial to address existing research gaps, particularly regarding rework origins. This study differs from previous studies in the following aspects:

(1) It comprehensively captures all construction rework causes without geographic boundaries.

(2) It provides quantitative and qualitative understanding of the current state of academic research on construction rework causes and offers valuable insights into trends and knowledge mapping.

Table 1.
Summary of review studies about construction rework causes

ID	Study	Focus of the study	Scope	Database	Period	Type of research	Main method	Software tool	Type of literature review
1	Asadi *et al.* (2021a)	Rework in construction	280 articles	Scopus, Web of Science, and Google Scholar	1990–2020	No bibliometric	Systematic literature review	Excel	Qualitative
2	Asadi *et al.* (2021b)	Causes of rework in construction contracts	157 papers	Scopus, Web of Science, and Google Scholar	1990–2020	No bibliometric	Systematic literature review	Excel	Qualitative
3	Safapour *et al.* (2022)	Organizational, project-based and human-based rework indicators	121 articles	Google Scholar, Science Direct, Scopus, and JSTOR	2000–2020	No bibliometric	Literature review and rank-sum method	–	Qualitative
4	Asadi *et al.* (2023)	Rework causes and their classification methods	157 papers	Scopus, Web of Science, and Google Scholar	1990–2021	No bibliometric	Systematic literature review	Excel	Qualitative

Source(s): Authors' own creation

3. Methodology

This study aimed to comprehensively analyze construction rework causes from a holistic perspective. Therefore, the research questions are as follows:

RQ1. What patterns emerge from the annual distribution of rework publications and citations and how do these patterns contribute to the domain of construction rework?

RQ2. Which countries are most actively contributing to research on construction rework?

RQ3. Which journals and researchers contribute significantly to research on construction rework?

RQ4. Which keywords are most prevalent in the corpus of construction rework publications?

RQ5. How are the key terms related?

RQ6. What temporal trends emerge from the analysis of keywords in construction rework over time?

RQ7. What are the dominant themes and patterns in the literature on construction rework?

RQ8. What are the origins of construction rework?

To achieve the study objectives and address the research questions, this study performed a comprehensive mixed review involving bibliometric and content analysis, encompassing metrological and thematic analyses, to explore the origins of rework. A visual representation of the research methodology is shown in Figure 1.

3.1 Mixed-methods systematic review and triangulation

This study conducted a literature review with the primary goal of identify the origins of construction rework, consolidating domain expertise and highlighting research gaps and prospects in the rework domain. A comprehensive review can streamline access to rework-related literature, preventing redundant efforts in the field. To accomplish this objective, a mixed-methods review, as outlined by Tashakkori and Teddlie (2010), was performed, with modifications tailored to the specificities of the reviewed topic. These adjustments encompassed variations in the chosen tool for conducting bibliometric analysis and the strategies employed to formulate and present research outcomes during both the bibliometric analysis (quantitative phase) and content analysis (qualitative phase). While the quantitative analysis provides us with numerical patterns and statistical evidence, the qualitative analysis lends depth and nuance to our exploration.

A mixed-methods systematic review combines qualitative and quantitative findings to address the overlapping. In this study, we adopted the methodology proposed by Oraee *et al.* (2017), using bibliometric analysis (metrological and keyword analysis) as the quantitative method and conducting content and trend topic analysis as the qualitative method. Triangulation using both quantitative and qualitative research to validate findings and complementation to integrate two distinct research methodologies to encompass various aspects of an investigation, were employed as mixed-methods strategies.

This mixed-methods approach aimed to achieve a comprehensive understanding of construction rework while mitigating the limitations associated with relying solely on either quantitative or qualitative methods, as highlighted by Gemci and Ferah (2020), Kalua (2023), Liu *et al.* (2020a), Oraee *et al.* (2017) and Rauf *et al.* (2020).

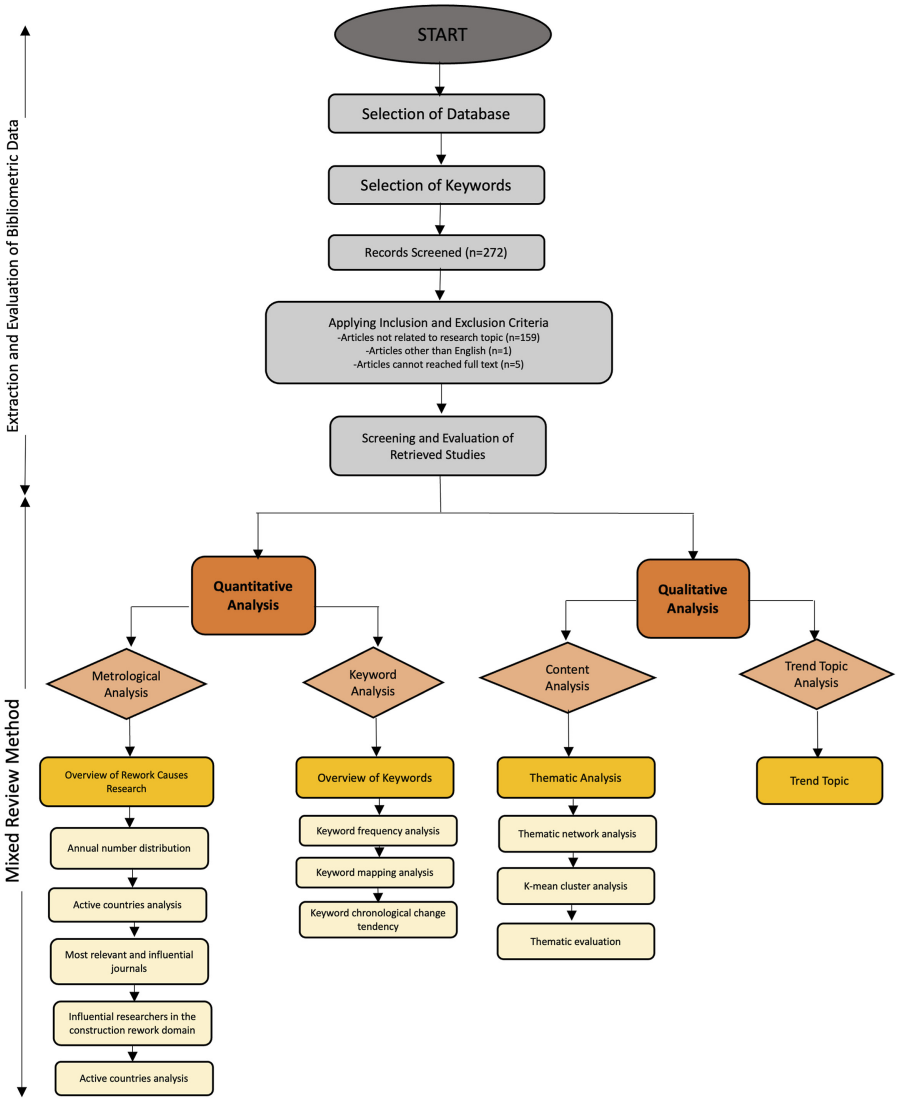

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Figure 1.
Methodology framework and data collection process

Triangulation is rooted in the principles of John Dewey's pragmatism (Dewey, 1908). Subsequently, Denzin (1978) established a conceptualization of triangulation, along with various associated methodologies or types. Triangulation is the integration of one or more research methodologies when investigating a phenomenon. The types of triangulations are as follows: (1) *data triangulation* entails combining various data collection techniques or sources; (2) *investigator triangulation* uses more than one researcher to collect data and/or interpret results; (3) *theory triangulation* uses multiple theories to explain the research problem, (4) *method triangulation* involves integrating multiple methods within a single study, such as employing

both quantitative and qualitative techniques for data collection and/or analysis. In the case of a single-method study, diversification within that method is used (Denzin, 1978).

Through method triangulation, we integrated quantitative (metrological and keyword analyses) and qualitative analyses (content and trend topic analyses). This integration provided a more comprehensive understanding of construction rework causes.

Metrological analysis encompasses the annual number distribution of articles, citations, *h*-index and keywords analysis, including keyword frequency, mapping and chronological change tendency served as the quantitative component. Content analysis includes thematic network analysis, cluster analysis, thematic evaluation and trend topic analysis, as qualitative.

3.2 Selection of database and keywords

Bibliometric analysis is a crucial component of our methodology. Bibliometric analysis is widely acknowledged for its enhanced reliability and impartiality compared with alternative methods (Chen *et al.*, 2018; Elshaboury *et al.*, 2022). It provides a crucial opportunity to gain insights into the characteristics and structure of a specific field in a systematic, transparent and reproducible manner (Liu *et al.*, 2017). This study involved in-depth author analyses, cluster analyses and thematic evaluations, focusing on causes of construction rework.

Bibliometric exploration involves meticulously selecting a database to obtain high-quality data for the subsequent bibliometric analysis. Choosing an appropriate search strategy and database(s) before gathering relevant construction rework studies for review purposes is crucial. To explore this research domain, this study selected the WoS, which is recognized as the premier database for bibliometric analysis (Yadav *et al.*, 2023). WoS was selected owing to its comprehensive coverage of key publications and inherent analytical capabilities that generate reliable metrics (Yu *et al.*, 2020). Furthermore, WoS employs advanced citation-matching algorithms that surpass those of Scopus (Valderrama-Zurián *et al.*, 2015), enhancing its value as the primary data source for this investigation (Song *et al.*, 2016).

Data extraction from WoS involved a preliminary search using specific keywords. The search query used was ALL FIELDS = "rework" AND "construction" AND "causes." This search was executed in September 2023, yielding 272 articles. Conference papers, books and book chapters were eliminated owing to widespread criticism that they were not subjected to a thorough peer review procedure (Shi *et al.*, 2020).

In acquiring these articles, establishing well-defined inclusion and exclusion criteria is crucial for efficiently filtering the collected research publications and retaining only the pertinent ones. Thus, specific inclusion and exclusion criteria were formulated to evaluate the literature. The inclusion criteria were as follows: (1) research explicitly addressing rework causes in construction projects and (2) studies published in peer-reviewed journals. Adopting a discerning approach concerning academic journals in the research domain is a strategic choice considering that such articles typically maintain higher quality standards, as supported by Shi *et al.* (2020). The exclusion criteria were as follows: (1) research published in languages other than English and (2) studies lacking readily available full-text resources. After applying the inclusion and exclusion criteria, 107 articles were retained.

3.3 Evaluation of the retrieved studies

The final phase involved an evaluation of the collected data. The 107 meticulously selected articles were analyzed using R programming for a thorough examination. Various article attributes, such as "abstract," "affiliation," and "author," were evaluated, with complete data records obtained for the majority. Minor discrepancies were noted in the "cited references" (less than 2%) and "DOI" (less than 6%). However, a significant 14.2% data gap in additional keywords was observed owing to author omissions (Table 2). Articles lacking keywords were excluded from the keyword-based analysis but were used in all other study procedures.

Metadata	Description	Missing counts	Missing %	Status
AB	Abstract	0	0.00	Excellent
C1	Affiliation	0	0.00	Excellent
AU	Author	0	0.00	Excellent
RP	Corresponding author	0	0.00	Excellent
DT	Document type	0	0.00	Excellent
SO	Journal	0	0.00	Excellent
LA	Language	0	0.00	Excellent
NR	Number of cited references	0	0.00	Excellent
PY	Publication year	0	0.00	Excellent
TI	Title	0	0.00	Excellent
TC	Total citation	0	0.00	Excellent
CR	Cited references	2	1.87	Good
DI	DOI	6	5.61	Good
DE	Keywords	11	10.28	Acceptable
ID	Keywords plus	15	14.02	Acceptable

Source(s): Authors' own creation

Table 2. The integrity of bibliographic metadata imported into the RStudio

3.4 RStudio Bibliometrix

The subsequent phase involved conducting a bibliometric analysis combining qualitative and quantitative methods using the RStudio Bibliometrix tool to construct a comprehensive map of the research landscape. In the realm of bibliometric analysis, several software platforms are available, such as VOSViewer, CiteSpace, SciMAT, CoPalRed and BibexCel (Cobo *et al.*, 2011). However, the intricate nature of many bibliometric analysis procedures implemented using these applications renders them complex for researchers seeking to analyze the literature (Aria and Cuccurullo, 2017). By contrast, the RStudio Bibliometrix tool, frequently employed in SLRs, extensively uses R-coded software (Alhawari *et al.*, 2021; Aria and Cuccurullo, 2017). This software encompasses functionalities catering to three distinct analysis levels—source, author and document—and offers three distinct approaches for assessing the knowledge structure within the reviewed literature: conceptual, intellectual and social. Furthermore, it offers more flexibility and incorporates graphical features borrowed from bibliometric tools.

Integrating quantitative and qualitative analyses in RStudio Bibliometrix allows for a more comprehensive understanding of research trends and scientific literature.

This study employed the RStudio Bibliometrix tool for the following primary purposes (Aria and Cuccurullo, 2017): (1) identifying the primary publication sources for articles in relevant topic areas; (2) determining the most-cited authors in those specific topics; (3) analyzing the keywords employed by authors to categorize article content; and (4) clustering keywords to reveal the fundamental structure inherent in the literature.

In summary, our methodology crosslinks quantitative and qualitative analyses through method triangulation, providing a robust foundation for addressing the research questions and contributing to a holistic understanding of the causes of construction rework. This integrated approach guides our subsequent analyses, results, conclusions and recommendations, aligning them seamlessly with the overarching research framework.

4. Findings

4.1 Quantitative analyses

4.1.1 Metrological analyses. The first phase of the quantitative analysis within the scope of bibliometric analysis was metrological analysis. This section presents the distribution of annual publications and their citations, analysis of active countries based on multiple

countries publications, single country publications ratios, most relevant journals based on the number of documents, researchers based on their *h*-index, total citations (TCs), number of publications (NPs) and citation analysis.

4.1.1.1 Distribution of publications and citations. Using RStudio Bibliometrix, insights into the yearly distribution of document volumes and their associated citations were extracted. This examination encompassed metrics, such as average annual citations, publication and cumulative citation counts, visually represented in Figure 2.

Figure 2 shows a consistent upward trajectory in the NPs addressing rework causes from 1991 to 2023, characterized by an annual growth rate of 7.11%, albeit with minor fluctuations. Notably, noticeable gaps existed in the years 1993–1996 and 1998–2001, when no studies on rework in the construction industry were conducted. The absence of pertinent research during this period could be attributed to several factors. First, research priorities may have shifted owing to evolving industry demands or the emergence of other critical issues, such as quality management, technology adoption (e.g. computer-aided design), construction safety and conflict resolution. Second, the significance of rework as a problem within the construction industry was not widely recognized or understood during those years. Researchers may not have been aware of the full extent of this issue or its potential impact on construction projects.

This upward trajectory reached its peak in 2022, marking a peak in publications on rework causes. This indicated a growing interest and popularity of the topic. The surge in research activity in 2022 can be attributed to several factors. Initially, a heightened acknowledgment of the importance of addressing rework issues within the construction sector was observed. These issues significantly affect project timeline, costs and overall project quality. Moreover, the adoption of cutting-edge technologies, such as building information modeling (BIM), drones, artificial intelligence (AI) and Internet of Things (IoT), within the construction industry may have served as a catalyst for increased investigation into their influence on rework causes and potential mitigation strategies. Additionally, the amplified scale and complexity of modern construction endeavors have further emphasized the importance of understanding rework causes. Megaprojects present unique challenges that have driven researchers to conduct more thorough investigations into the complexities

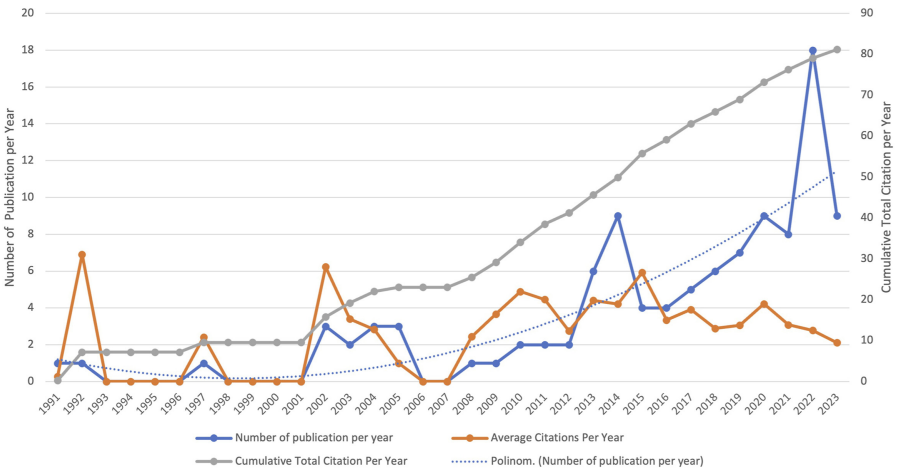


Figure 2.
Distribution of rework cause publication citations

Source(s): Authors' own creation

surrounding rework causes. Furthermore, considering the data collected until September 2023, the NPs within this domain is expected to surpass that in 2022 by the end of 2023.

An examination of the cumulative TC trend across the years revealed a persistent and steady increase, indicating the growing popularity of the subject of rework causes. Conversely, the average number of citations per year fluctuated, with variations observed from one year to the next.

4.1.1.2 Active countries analysis. A comprehensive analysis of the data generated by the RStudio revealed active participation in research related to rework causes in 26 countries. Table 3 highlights the top 10 nations based on their publication counts, as reported in the program's statistical data.

As shown in Table 3, Australia predominated with a significantly higher NPs compared with other countries. This increased research output in Australia can be attributed to the nation's awareness and educational efforts aimed at addressing rework causes. The close collaboration between academia and the construction industry in Australia played a pivotal role in this research dominance. Collaborative initiatives with construction companies, industry associations and government bodies enable access to real-world data and provide vital support for research endeavors focused on addressing industry challenges.

Australia dominated in terms of publication volume and emerged as the most actively collaborative country, engaging in research efforts involving multiple nations. Conversely, New Zealand, Nigeria and Saudi Arabia notably lacked collaborative efforts. Malaysia was the most proportionately collaborative country based on the Multiple Countries Publications (MCP)/Single Country Publications (SCP) ratio.

4.1.1.3 Most relevant journal. Articles addressing rework causes are distributed across a wide range of journals. The dataset, comprising 107 articles on rework causes published from 1991 to 2023, encompassed contributions from 51 unique journals. The quantification of articles focusing on rework causes in the construction industry serves as a metric for identifying the most influential journals in this domain. Figure 3 shows the top-ranked journals with the highest publication outputs related to rework causes.

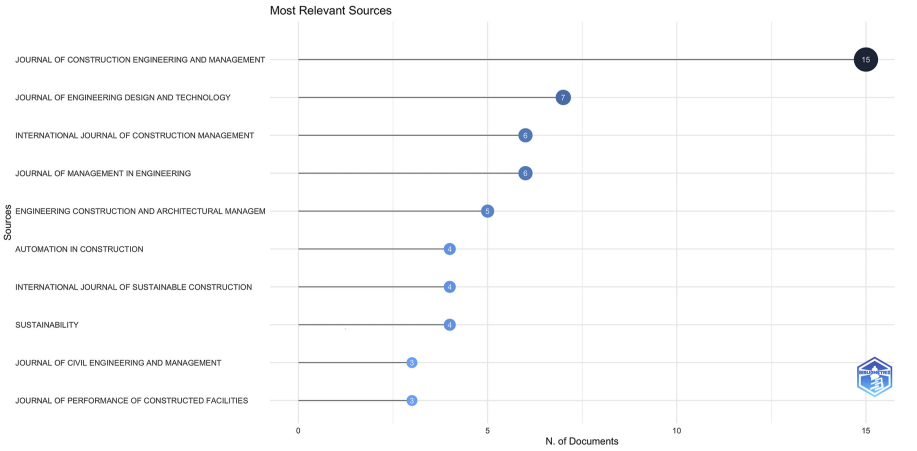
Figure 3 shows that numerous journals play crucial roles as focal points for research on rework causes. The *Journal of Construction Engineering and Management, Journal of Engineering Design and Technology, International Journal of Construction Management, Journal of Management in Engineering and Engineering Construction and Architectural Management* were notable contributor journals to research rework causes.

Notably, these five journals have consistently accepted articles spanning a broad spectrum of topics related to rework, including managerial aspects, the impacts on project performance, benchmarking, rework cost analysis and improvement mechanisms. These

Country	Articles	SCP	MCP	MCP/SCP ratio
Australia	20	5	15	0.750
China	11	4	7	0.636
USA	10	9	1	0.100
Malaysia	8	1	7	0.875
Iran	7	3	4	0.571
Korea	7	2	5	0.714
New Zealand	5	5	0	0.000
Nigeria	4	4	0	0.000
Canada	3	2	1	0.333
Saudi Arabia	3	3	0	0.000

Source(s): Authors' own creation

Table 3. Total number of articles, SCP, and MCP by the most active 10 country



Source(s): Authors' own creation

Figure 3.
Top 10 journals significantly contributing to research on rework origins

thematic alignments are closely related to rework causes, contributing to a strong association with the high acceptance rate of research papers in these esteemed journals.

4.1.1.4 Pioneering researchers. Most scholars in the field have identified rework causes through a comprehensive analysis of author details within the compiled dataset. Table 4 summarizes the essential quantitative indicators, including the *h*-index, TCs, NPs and the inception year of their initial contributions to the construction rework field (PY-start). This tabulated information pertains to the top 10 distinguished authors who have made substantial contributions to the literature on construction rework.

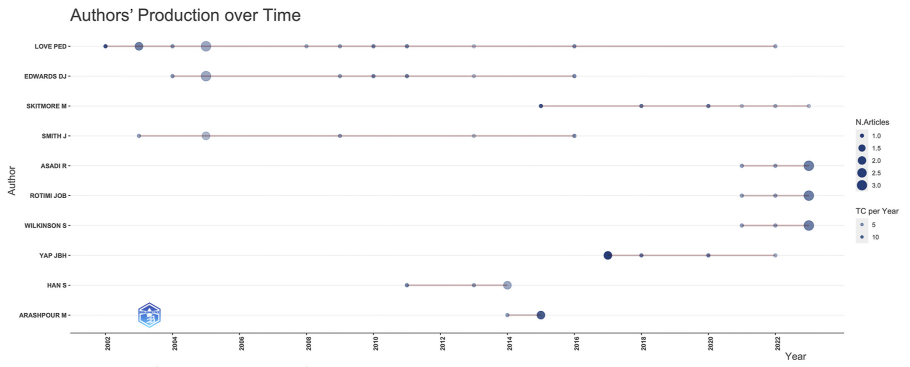
As shown in Table 4, Love PED stood out as the preeminent authority in the field, characterized by the exceptional *h*-index, TC and NP. Edwards DJ and Smith J closely followed in terms of the *h*-index.

Figure 4 shows the scholarly contributions of authors over time. The size of the circles in the figure corresponds to the scale of their output, expanding proportionally with the NP each year. Notably, Yap JBH achieved the highest TC/Y ratio (13.85) in 2017, followed by Love PED in 2002 (11.77) and Skitmore M in 2015 (11.22). These findings suggest that their research efforts during these years had a more significant impact than those of other researchers.

Author	h-index	TC	NP	PY-start
Love PED	11	872	14	2002
Edwards DJ	9	425	9	2004
Smith J	6	213	6	2003
Han S	4	154	4	2011
Skitmore M	4	178	6	2015
Yap JBH	4	171	5	2017
Arashpour M	3	130	3	2014
Asadi R	3	25	5	2021
Mahamid I	3	42	3	2016
Rotimi JOB	3	25	5	2021

Source(s): Authors' own creation

Table 4.
Top ten pioneering researchers in the field of rework causes



Source(s): Authors' own creation

Figure 4.
Productivity trends of the top 10 scholars in the rework research field over time

4.1.1.5 Citation analysis. This study performed a citation analysis to identify and explore the most frequently referenced publications on construction rework. Table 5 lists the 10 most-cited publications on rework causes and their global citations (GCs), ranked in descending order by the number of local citations (LCs). LC is the frequency with which a document is cited by papers within the collected dataset (comprising 107 documents). This serves as a metric indicating the impact of these papers within the research domain. GC is the number of

Document Author	Journal	Year of publication	LC	GC	TGC/Y	Subject
Josephson PE	*Journal of Management in Engineering*	2002	44	129	5.86	Benchmarking rework and rework cost
Ye G	*Journal of Management in Engineering*	2015	25	101	11.22	Causes of construction reworks
Love PED	*Civil Engineering Environment System*	2004	22	78	3.90	Causes of construction reworks
Love PED	*Journal of Management in Engineering*	2003	21	72	3.43	Benchmarking, benchaction, and benchlearning rework mitigation
Hwang BG	*International Journal of Project Management*	2014	21	83	8.30	Client-related rework
Yap JBH	*Journal of Engineering, Design and Technology*	2017	14	44	6.29	Impacts, causes and solutions of rework
Mahamid I	*Jordan Journal of Civil Engineering*	2016	12	19	2.38	Analyzing causes of rework
Oyewobi LO	*Journal of Engineering, Design and Technology*	2016	12	26	3.25	Impact of rework
Taggart M	*Construction Management and Economics*	2014	10	36	3.60	Role of supply chain in rework
Safapour E	*Journal of Management in Engineering*	2019	7	49	9.80	Early indicators of manageable rework causes

Source(s): Authors' own creation

Table 5.
Top 10 cited papers in rework causes research field

times a paper is cited in the WoS core collection database. This indicates its prominence within the circle of the WoS core collection database.

The study by Josephson *et al.* (2002) achieved the highest LC and GC scores of 44 and 129, respectively. The total global citations per year (TGC/Y) metric was used to highlight the impact of the publication year of an article. Hwang and Yang (2014), Safapour and Kermanshachi (2019) and Ye *et al.* (2015) occupied the top three positions in terms of TGC/Y, indicating the relevance of these studies in the research domain.

4.1.2 Keyword analyses. Keyword frequency analysis, keyword mapping and temporal trends of keyword analysis, serving as crucial elements of broader quantitative analysis, have been used within the scope of keyword analyses.

4.1.2.1 Keyword frequency analyses. In the context of this research, a comprehensive set of 338 keywords extracted from 107 articles was used for the bibliometric analysis. Some keywords had synonymous or similar meanings that could introduce inaccuracies. Unlike other bibliometric software packages, the R-tool can consolidate these terms and address potential challenges by grouping similar words under primary representatives, as shown in Table 6, to enhance keyword analysis accuracy.

Figure 5 shows the most frequently used keywords and their respective frequency of occurrence in the analyzed articles within the field. The term "cost" emerged as the most prominent keyword, followed by "rework." This observation is consistent with the central focus of this research, which investigates rework causes.

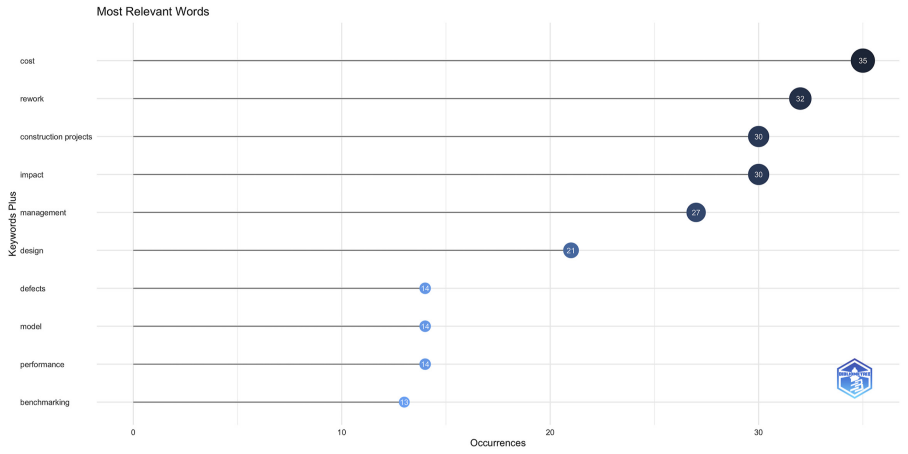
4.1.2.2 Keyword-mapping analysis. Keyword mapping was initiated after categorizing and consolidating synonyms. Keyword mapping aims to elucidate the structural and dynamic facets of scientific research using a knowledge framework. The authors select keywords for an article, whereas indexers define keyword-plus terms to represent the article content more precisely. Therefore, in contrast to previous review studies in this domain, this review used keyword-plus terms. Data derived from keyword-plus terms were used in the keyword-mapping analysis.

The WalkTrap algorithm, known for its effectiveness in identifying term communities, was used to construct a co-occurrence network for visualizing keyword mapping (Pons and Latapy, 2006). This algorithm assesses the arrangement of specific terms, creates nodes, classifies them into clusters and groups similar nodes within the community (Pons and Latapy, 2006). Links are established between words that co-occur in the articles. By visually representing this co-occurrence network, the interconnections among studies related to rework causes are revealed, providing insights into the underlying patterns and connections.

Table 6.
Matched words

Word	Consignification
construction projects	building construction projects; projects; building projects; project
defects	error; failure; errors; failures
barriers	constraints
causative factors	causation; reasons
cost	costs
delay	delays
exhaustion	fatigue
impact	impacts
system	systems
work	works
triggers	enablers

Source(s): Authors' own creation



Source(s): Authors' own creation

Figure 5.
Top 10 frequently used keywords in studies on rework causes

Figure 6 illustrates the interconnected network of keywords within publications addressing rework causes. The size of the circles corresponds to the frequency of word occurrence in the dataset. The connections between them represent co-occurrence, and the thickness of the connections indicates the frequency of simultaneous usage in publications. Colors denote clusters of words sharing strong associations.

Figure 6 shows that the term "rework" exhibited strong associations with the words "management," "impacts," "defects," "performance," and "delay." Similarly, the terms "impacts of rework" and "management" demonstrated strong associations with the words "design" and "quality."

4.1.2.3 Temporal trends of keywords. For a more comprehensive understanding of how subjects have evolved over distinct time intervals, keyword trends over the last 2 decades were analyzed. Figure 7 shows the changing frequency of keyword usage over time,

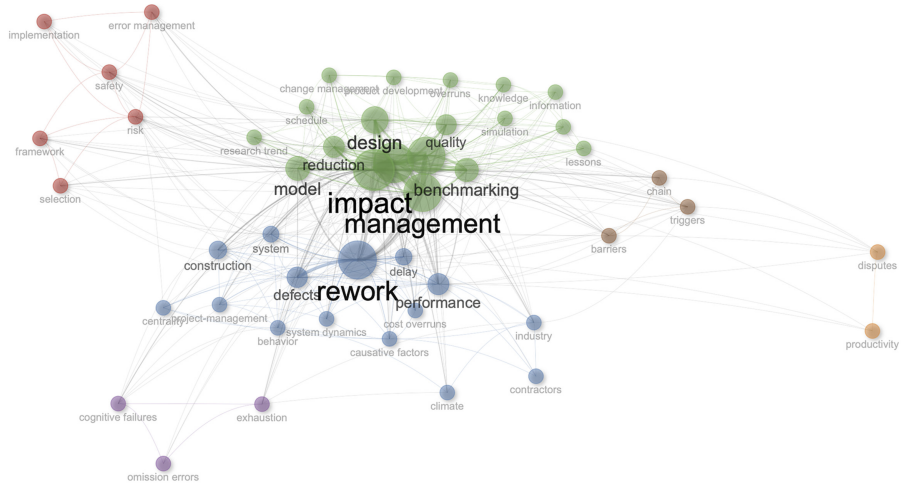


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Figure 6.
Keyword-plus co-occurrence network analysis

providing valuable insights into the evolving patterns of keyword utilization. The predominant keywords within the dataset included "costs," "design," "impact," "management" and "rework."

Figure 7 shows that early studies in this domain initially focused on the term "design" in 2002. In subsequent years, research began to address issues related to costs, particularly in 2005. This shift can be attributed to the challenges associated with cost overruns owing to design problems. As research progressed, various other parameters were investigated. The emergence of the keyword "management" in 2009 aligned with the expanding scope of inquiry. This indicated a broader exploration of construction management, including project management, cost estimation and control, quality management and risk management.

Keywords, such as "change management", "cost management," and "scheduling" are often associated with the management field. This association can be attributed to the increased research on "management" in the construction rework context in 2009. In 2017, the term "management" surpassed other terms in discussions regarding construction rework causes. Throughout the time span represented in the graph, the term "design" exhibited significantly lower usage than other terms. By contrast, "design" was the first term to be introduced, exhibiting an accelerated increase in interest between 2018 and 2020. By 2023, the term "rework" had gained the highest attention, followed by "management," exhibiting an increased momentum compared with other keywords.

4.2 Qualitative analyses

4.2.1 Content analyses. 4.2.1.1 Thematic network analysis. Thematic mapping uses a two-dimensional framework to categorize keywords and visualize their impact (Aydınoğlu *et al.*, 2022). Circles represent clusters of related words, with sizes indicating publication associations. The vertical and horizontal axes in the diagram represent density and centrality, respectively (Cobo *et al.*, 2011; Karakose *et al.*, 2022). Density indicates the interconnectedness among the themes within a circle. The cluster is positioned higher in the diagram when the relationships among words within a cluster are strong. Moreover, density reflects the growth potential of words within a cluster. Centrality illustrates the interactions between a specific cluster and others. In essence, as the interaction of a specific cluster with other clusters increases, it shifts toward the right in the diagram (Cobo *et al.*, 2011; Karakose *et al.*, 2022).

The strategic diagram in Figure 8 shows that "Motor" themes (Quadrant I) are pivotal and influential, whereas "Niche" themes (Quadrant II) are specialized but might lack context or importance. "Emerging/declining" themes (Quadrant III) appear infrequently or may fade, requiring a qualitative analysis. "Basic" themes (Quadrant IV) are relevant but less explored despite their significance owing to high centrality (Cobo *et al.*, 2011; Karakose *et al.*, 2022).

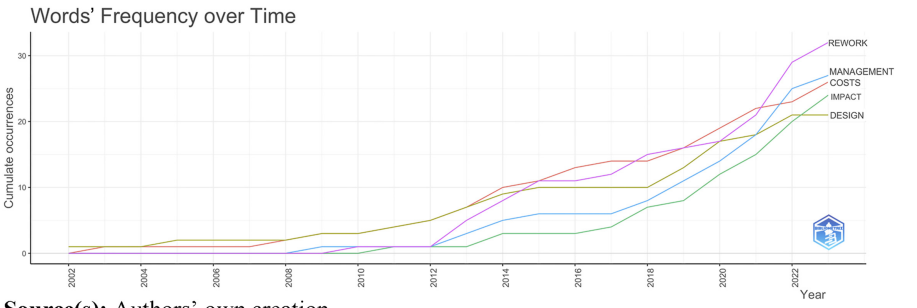

Figure 7.
Frequency of word usage over time

Source(s): Authors' own creation

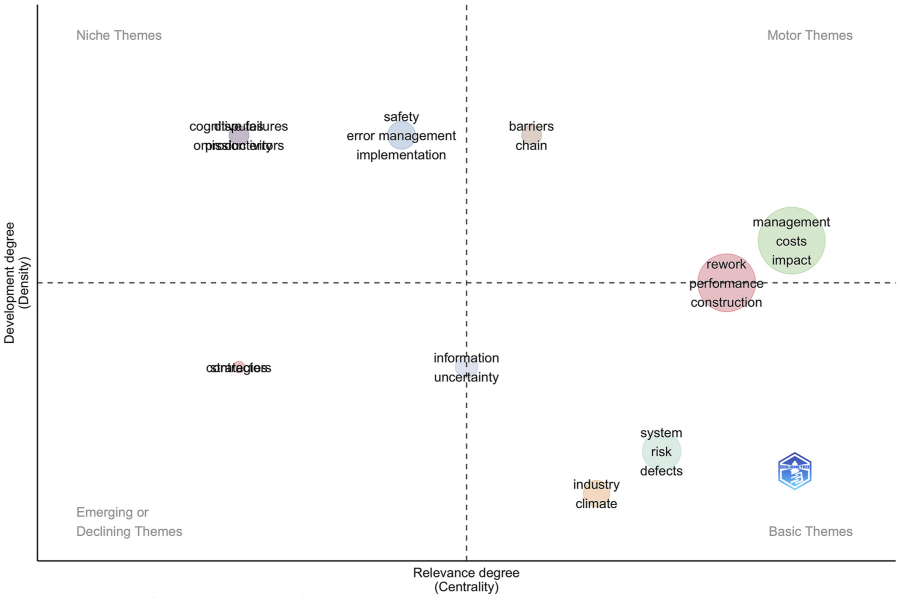

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Figure 8.
Thematic mapping

A thorough examination of the clusters under "Motor" themes revealed that specific concepts, such as "management," "cost," and "impact," are crucial and possess significant potential for further advancement. The cluster sizes indicate that the majority of publications incorporated words within these clusters. Additionally, other clusters of subjects, such as "barriers" and "chain," have emerged as notable instances under "Motor" themes. This indicates that the first set of concepts was pivotal to the advancement of the field, demonstrating internal and external connections (Figure 8).

The cluster comprising "rework," "construction," and "performance" is positioned precisely along the centrality axis, indicating the highest centrality and moderate density within clusters. The placement of this cluster suggests the significance of these concepts, despite the need for more extensive research on such topics.

Themes such as "safety," "error management," "cognitive failures," "disputes," and "productivity" fall under "Niche" themes in the second quadrant. This indicates that these themes are well developed but relatively isolated within the research context. Although they may have strong relationships, they may not be significantly influential in research related to rework causes.

A comprehensive analysis of clusters under Quadrant II and one cluster in Quadrant I revealed a distinct pattern, demonstrating a horizontal alignment. This suggests a consistent level of interaction with other clusters over time. Notably, the theme encompassing "barriers" and "chain" exhibited the highest level of interaction within this group. Furthermore, the themes "cognitive failures," "disputes," "productivity," "barriers," and "chain" had less contributions to research on rework causes, as indicated by their cluster sizes.

The terms "contractors" and "strategies" are positioned in the third quadrant, under "Emerging" or "Diminishing" themes. This suggests that these themes hold limited significance and warrant further qualitative analysis.

The fourth quadrant represents the "Basic" themes, which are significant concepts in the field that have not been extensively explored. Key themes, such as "system," "risk," "defects," "industry," and "climate" fall under this category. Although the clusters in this quadrant exhibited weak internal connections, they demonstrated strong associations with other clusters.

4.2.1.2 Cluster analysis. A cluster analysis was performed to examine the presence of distinct groups within the dataset. The K-means clustering method was employed, involving a correlation analysis of the co-citation matrix. To determine the most appropriate number of clusters, k = 2, 3 and 4 were tested. At k = 4, only one element existed within the cluster (Figure 9a), lacking significance to constitute a distinct cluster (Raza, 2020). Consequently, using the k-means clustering algorithm with k = 3 in this study yielded coherent and meaningful clusters (Figure 9b).

Based on the clustering formed through K-mean analysis, Cluster 1 in red color is defined as "human- and contractual-based rework causes," Cluster 2 in blue color is defined as "design-, quality-, and project management-based rework causes," and Cluster 3 in green color is defined as "organizational-based rework causes."

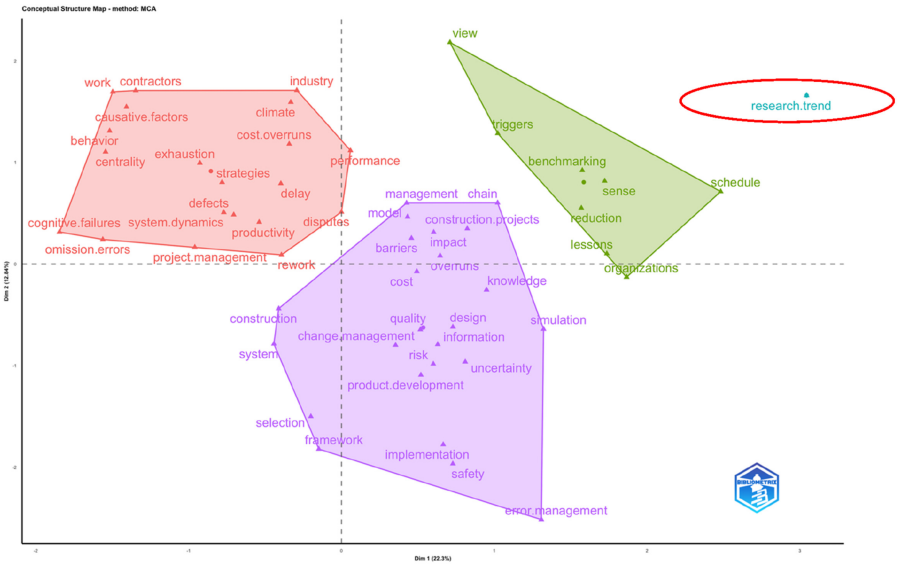
4.2.1.3 Thematic evaluation. This study involved an analysis of articles within the database, with the findings visually represented using three area graphs. The connections between these areas were demonstrated using Sankey diagrams (Figure 10). Sankey diagrams, recognized as valuable tools for tracking thematic progression, are essential for illustrating the flow across diverse networks and processes (Shi *et al.*, 2020). Examining these diagrams reveals the developmental trajectory of processes and intellectual associations within the domain, offering valuable insights into the temporal evolution of a subject. This study also incorporated thematic evaluation, a crucial component that examines whether key concepts in the field have changed over time. This evaluation process deepens the understanding of the evolution and adaptation of fundamental concepts (Riehmann *et al.*, 2005).

This study examined the evolution of rework research across three distinct periods: 1991–2011, 2012–2020 and 2021–2023. Rework-related research began in the early 1990s. Adequately understanding construction costs before embarking on a construction project is crucial. It aids in formulating a comprehensive budget plan encompassing all expenses necessary for project completion. Subsequently, this projection is compared with available finances to ascertain the feasibility of the project. In a broader context, rework incurs costs exceeding $177 billion annually in the USA alone (Dustyrobotics, 2023). This substantial financial burden has significant implications. Consequently, from 1991 to 2011, rework-related research primarily focused on exploring themes, such as "cost" and "construction process." As research progressed, it expanded and delved deeper into the field.

Identifying rework is imperative in construction projects. Rework often results in delays, diminished organizational performance and contractual claims, particularly cost overruns (Love and Smith, 2003). Consequently, cost constituted one of the initial study themes in construction rework. This concept retained its significance from 2012 to 2020. Nevertheless, after 2020, the theme evolved into "rework," "design," and "construction projects." Various themes within the industry are expected to be continuously explored until 2023.

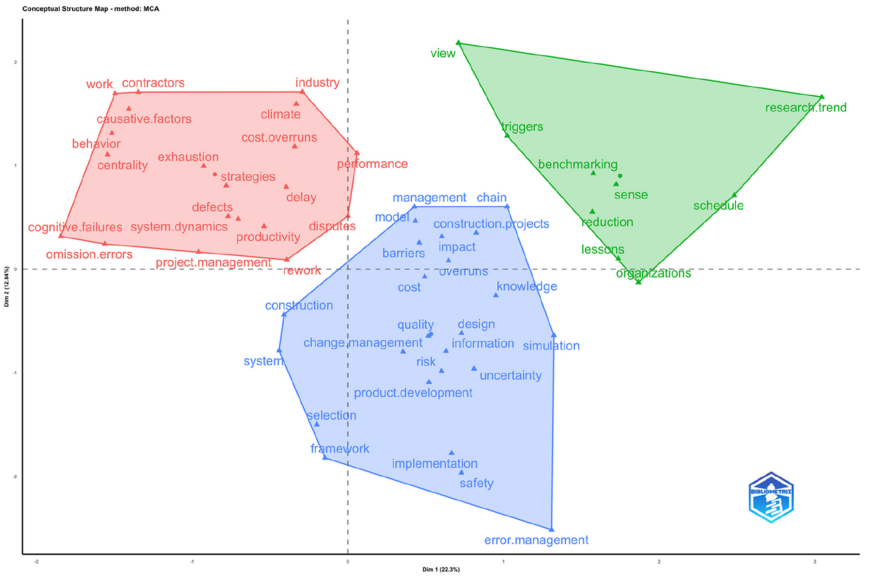
Over time, the term "construction" underwent a notable evolution, encompassing diverse themes, such as "defects," from 2012 to 2020. It can be assumed that studies investigating construction-related rework causes from 1991 to 2011 revealed that defects were among the most significant contributors. Figure 11 illustrates this argument. After 2020, the theme "defects" evolved into "rework" and "project management."

Notably, the emerging themes in 2012–2020 were "performance," "quality," and "system." "Performance" and "system" evolved into "rework" during 2021–2023 period.



Cluster analysis with $k = 4$

(a)



Cluster analysis with $k = 3$

(b)

Source(s): Authors' own creation

Figure 9.
Cluster detection with factorial analysis

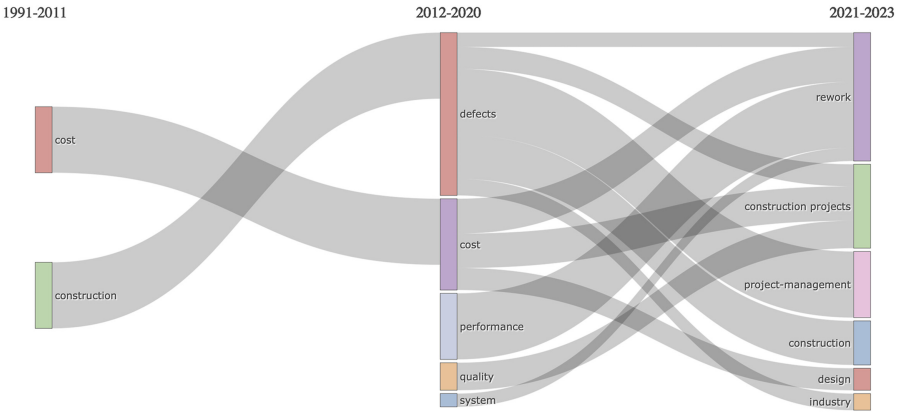


Figure 10.
Thematic evaluation of research on rework causes (1991–2023) using Sankey diagrams

Source(s): Authors' own creation

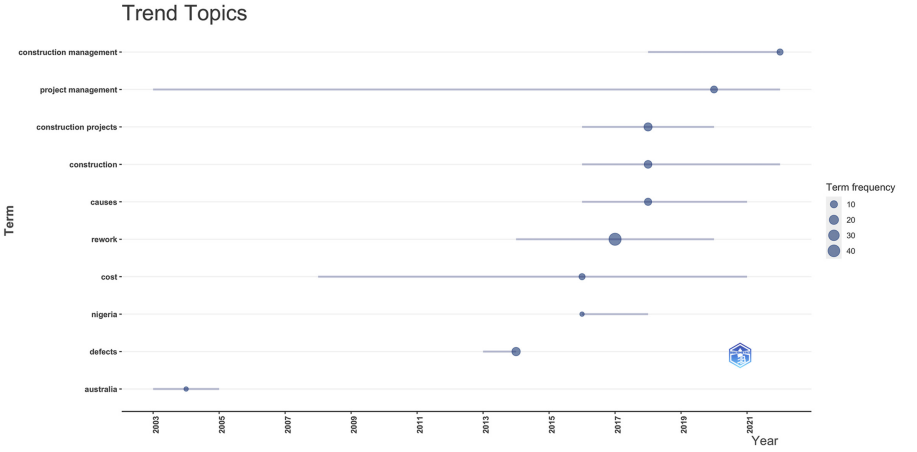


Figure 11.
Trend topics in rework causes

Source(s): Authors' own creation

4.2.2 Trend topic analysis. Trend topic analysis reveals the prominence of specific core concepts in publications spanning several years. The dimensions of the circles are associated with the frequency of theme utilization, with larger circles indicating more frequent theme usage. Figure 11 shows that research on rework causes in recent years exhibited prominent trends in various areas. These include "construction management," "project management," "construction projects," "construction," "causes," "rework," "costs," "Nigeria," "defects," and "Australia." Figure 11 shows that "rework" has been the most frequently used theme since 2014 and remains a focus of interest among researchers. The word "defects" trended between 2013 and 2014; however, interest on this theme declined after 2015, replaced by rework causes and construction management-related topics. This indicates that most studies on rework causes were often associated with management-related aspects. This implies that researchers have focused on identifying rework causes rather than preventing and minimizing rework.

5. Discussion

This study used a comprehensive, reliable and top-quality dataset comprising 107 scholarly articles on rework origins. These articles were published between 1991 and 2023, sourced from the WoS database. Research on the factors contributing to rework was conducted from multiple perspectives with mixed review methods and analyses. Quantitative analyses included the annual distribution of published article, influential countries, leading researchers, significant construction rework-related journals and keyword analyses. Qualitative analyses included thematic and trend topic analyses.

(1) Despite the long-standing research on construction rework, a notable increase in research activities focusing on construction rework causes has been observed since 2013, reaching a peak in 2022. This trend highlights the heightened awareness and emphasis on understanding construction rework causes over the past decade (Figure 2).

(2) An examination of the countries with the most significant influence in this field revealed that Australia has dominated this research field (Table 3). Love and Smith (2003) highlighted the Australian government's efforts in issuing multiple directives aimed at enhancing the performance of the construction industry. Rework was identified as a major contributor to subpar organizational and project performance (Love, 2002). Additionally, Table 3 underscores Australia's remarkable standing as the most collaboratively engaged country, relative to others, in this context.

(3) The examination conducted in this study identified the *Journal of Construction Engineering and Management*, *Journal of Engineering Design and Technology*, *International Journal of Construction Management*, *Journal of Management in Engineering* and *Engineering Construction and Architectural Management* as the most notable publications (Figure 3).

(4) Love PED was identified as the most prominent researcher in the field in terms of *h*-index performance, followed by Edwards and Smith J (Table 4).

(5) One aspect distinguishing this study from previous bibliometric analyses is the use of keyword-plus analysis. While researchers typically assign keywords, indexers provide keyword pluses to enhance comprehension of the theme, subject matter and article content. In this investigation, keyword pluses were employed as the research focus for article contents. Notably, themes such as "cost," "design," "impact," "management" and "rework" were identified as subjects of substantial interest for future research. This was evidenced by the apparent rise in attention gained over time (Figure 5).

To delve deeper into the construction rework domain and to emphasize the core semantic themes inherent in textual data and reveal the thematic evolution within the field, various qualitative methodologies were employed, including conceptual structure mapping, co-occurrence networks with temporal data and Sankey diagrams.

(1) Thematic mapping and assessments were conducted to enhance the validity of this study and generate insights for future research. Figure 8 shows the thematic mapping procedure. The figure reveals that the most pivotal research areas within the subject were the emerging themes of "management," "cost" and "impact" within the overarching "Motor" theme. By emphasizing rework management, project and rework expenses can be minimized while mitigating the adverse consequences of rework. In addition, the concept of "strategies" that emerged in the 3rd quadrant of Figure 8 is associated with the novelty of strategies for minimizing the construction

rework theme. This may be because rework minimization strategies are open to research in the rework field.

(2) A single-keyword analysis may not offer comprehensive results. Thus, this study employed the k-means clustering method. The use of this method is one of the features distinguishing this study from other limited bibliometric analyses. In contrast to previous studies, this study created conceptual clusters by applying the k-means method to the keyword-plus network. Figure 9 shows the outcomes of multiple attempts to determine the optimal number of clusters, ultimately identifying four clusters as the most suitable. After a thorough examination of the terms within each cluster, three clusters were categorized as follows: (1) human- and contractual-based; (2) design-, quality- and project management-based; and (3) organization-based.

- *Human- and Contractual-Based Rework Causes:* A significant number of errors occurred on-site in both projects, necessitating rework. Many of these errors originate from issues involving clients, contractors and subcontractors. While previous research has categorized rework causes into client-, contractor- and subcontractor-related causes, these causes fall under human-based rework causes. Clients play the most influential role in project decision-making processes. Numerous prior studies (Eze *et al.*, 2018; Forcada *et al.*, 2014; Love *et al.*, 2013; Mahamid, 2016; Yap *et al.*, 2017) have identified clients as the primary contributors to construction rework. Therefore, frequent client-initiated variation orders can lead to rework (Enshassi *et al.*, 2017). In addition, Love and Smith (2003) argued that the lack of communication between clients and design consultants significantly contribute to rework. Alwi *et al.* (1999) suggested that effective supervision and skilled labor are fundamental prerequisites for successful construction projects and are inversely related to rework costs. Contractor- and subcontractor-related factors are significant sources of human-based rework. Contractor- (Enshassi *et al.*, 2017; Eze *et al.*, 2018; Ye *et al.*, 2015) and subcontractor-related factors (Love and Edwards, 2004; Ye *et al.*, 2015) are significant factors influencing rework in various countries. Furthermore, Liu *et al.* (2020a) reported that contractors and subcontractors accounted for 20.10 and 10.54% of the total rework cost in Chinese residential buildings, respectively. Love (2002) highlighted that inadequate contract management can be a catalyst for rework stemming from issues within the contract or design documentation. Furthermore, Love *et al.* (2010) contended that, in projects with stringent design schedules, members of the design team often resort to reusing details and specifications to alleviate their workload. Such practices can lead to incomplete design information, affecting the construction process and resulting in rework. Rounce (1998) noted that poorly reviewed drawings, inappropriate drawing scales and design changes requested by clients significantly contributed to a substantial amount of rework. Similarly, Love and Edwards (2004) emphasized that insufficient time and resources allocated to the briefing and contract documentation processes can lead to rework. While human- and contractual-based rework causes may appear as independent variables, the cluster analysis in Figure 9 demonstrated their interdependence. Managing human resources in construction projects is challenging (Yap *et al.*, 2020) because personal attitudes, such as a lack of contractual knowledge, can significantly impact rework and claims (Wang *et al.*, 2019). This further highlights the importance of human resources as a key solution for effective claims management (Jalal and Moharreri, 2020; Seo and Kang, 2020).

- *Design-, Quality- and Project Management-Based Rework Causes:* Quality failures and subsequent rework have been primarily attributed to design-related issues, such as inaccurate documentation and inadequate communication among team members (Hwang and Yang, 2014). Rounce (1998) identified specific rework activities with adverse effects on the profit margins of architectural firms. These include redesigns prompted by insufficient project briefs, modifications resulting from unchecked drawing problems, redesigns owing to inappropriate drawing scales and addressing design changes requested by clients. Diminishing profits in architectural firms often stem from a lack of emphasis on effectively managing the documentation process, leading to frequent rework occurrence (Love *et al.*, 2004). Design-related issues often stem from a deficient quality management system, constituting a root cause of construction rework. Tilley and McFallan (2000) reported that many Australian design organizations lacked a formal quality assurance (QA) system and did not consider International Organization for Standardization (ISO) 9000 certification a crucial aspect of their management practices. The Building Research Establishment in the UK recognized the need for a structured and systematic approach to quality control in the construction industry. Rounce (1998) recommended that architectural firms enhance their profitability by improving internal management practices, focusing on quality management, particularly QA. Lomas (1996) reported that implementing a QA system reduced rework from an average of 5% to less than 1% of the contract value in most projects. This emphasized the significance of sound management practices. In project management, inadequate integration and a lack of timely and effective communication are recognized as significant catalysts for project problems (Arain and Pheng, 2006), potentially leading to project failure (Abd El-Razek *et al.*, 2008). Arain and Pheng (2006) reported that when communication failures occur, contractors are unable to access crucial information, delaying the completion of project objectives. Operating with outdated information can have detrimental effects on projects, such as rework, schedule delays and a reduced quality. Furthermore, the complex and multifaceted nature of subcontracting can complicate the coordination processes (Ye *et al.*, 2015). Efficient project management is crucial for minimizing alterations, mistakes and omissions during the construction process (Love *et al.*, 2004). Rework costs can be minimized by addressing managerial deficiencies and implementing best practices in the construction process, making them manageable and controllable (Safapour and Kermanshachi, 2019). Consequently, the support provided by managers to the workforce and the prioritization of project safety are crucial in this regard (Mohammadi *et al.*, 2018; Zhao *et al.*, 2010).
- *Organizational-Based Rework Causes:* Ineffective organizational communication and coordination have been identified as significant factors leading to rework during the execution of construction projects (Alaloul *et al.*, 2016; Lotfi and Ghaderi, 2013; Safapour *et al.*, 2022). Hwang and Yang (2014) argued that inadequate coordination can lead to deviations from necessary requirements, amplification of redundancies and loss of critical data and information. Ineffective coordination can lead to increased error frequency and cost, increasing rework expenses. Malisiovas and Song (2014) defined organizational communication as the effective collaboration in mutual tasks. Chinowsky *et al.* (2011) considered it a pivotal link to project success through knowledge sharing during project execution. Numerous authors and researchers have emphasized that effective organizational communication is crucial for project success. By contrast, poor

communication within an organization often results in more design alterations. More communication is needed to ensure the sharing of essential data and information, leading to increased redundancy, duplication and errors (Cheng *et al.*, 2001; Forcada *et al.*, 2017; Lee and Kim, 2018; Safapour *et al.*, 2022).

(3) "Cost" and "construction" were the primary research themes in this field between 1991 and 2011. However, a shift occurred in the years 2012–2020, encompassing "defects," "performance," and "quality." After 2021, prominent topics included "rework," "construction projects," "project management," "design," and "construction" (Figure 10). This study demonstrated a clear trajectory for rework exploration. Additionally, the analysis in Figure 10 indicates that rework causes are frequently addressed through project management. This highlights a potential avenue for further research to investigate the interrelation between construction management and rework. Another research direction is investigating all phases of the construction process, the related stakeholders and their associated rework causes.

6. Conclusion

This study provides a comprehensive literature mixed review of the origins of construction rework. Over a hundred research articles have been published for nearly 25 years (1991–2023), aiming to address and minimize the adverse effects of rework. Although diverse causes of construction rework have been identified across countries, a holistic conceptual framework comprehensively connecting these root causes remains lacking. This study aimed to create a thorough map of construction rework origins through the following steps: (1) identifying influential scholars and journals in the field, (2) determining primary keywords and research themes, (3) proposing potential research avenues through bibliometric and network analyses, (4) categorizing rework origins via cluster analysis and (5) highlighting thematic shifts in the construction rework domain through thematic analysis.

The findings revealed a pronounced increase in research on construction rework in recent years. A particularly rapid surge was observed after 2021. This can be attributed to the impact of the COVID-19 pandemic on the construction industry, particularly in terms of human resources and contractual dynamics. The most substantial contributions to the research community originated in Australia, China and the USA, with 20, 11 and 10 research papers, respectively. Prominent keywords in this field included "cost," "rework," "construction projects," "impact," and "management." In terms of the most influential authors, among the 247 contributing authors from 1991 to 2023, Love PED had the highest *h*-index, NP and TC, followed by Edwards DJ and Smith J. Notably, the most influential journals in the construction rework domain included the *Journal of Construction Engineering and Management, Journal of Engineering Design and Technology, International Journal of Construction Management, Journal of Management in Engineering, Engineering Construction* and *Architectural Management*.

Furthermore, the findings revealed three major construction rework origin clusters: human- and contractual-based, design-, quality-, project management-based and organizational-based rework causes. Construction rework topics exhibited a strong association with terms such as "project management," "design," and "construction projects" after 2022, emphasizing their critical relevance in recent research.

The outcomes of this study hold significance for engineering, architectural and construction firms, providing insights into the root causes of construction rework. In this context, the study carries empirical and managerial implications, delineated below.

6.1 Conceptual and empirical implications

This study identified the origins of construction rework using a holistic approach. To the best of our knowledge, previous studies have not investigated the origins of construction rework with an integrated approach using bibliometric analysis. The number of annual publications and citations were identified in the study's first phase of quantitative analyses. These results contribute to understanding the temporal trends and evolution of research in this field. This analysis revealed periods of increased attention, emerging themes and shifts in focus over time, Providing researchers and practitioners insights into the dynamic nature of the rework causes. These results help gauge research interest and productivity over time, offering a snapshot of the field's vibrancy. The active country analyses contextualized the construction rework causes within specific countries. The second phase of quantitative analysis was keyword analysis, which contributed by refining the conceptual framework of construction rework causes and identifying key themes and relationships that shape the discourse within the literature. The keyword frequency analysis identified dominant themes, providing a quantitative understanding of the most prevalent topics within rework cause studies over time. Keyword mapping contributed empirically by visually representing interconnected concepts, offering insights into the relationships between different aspects of construction rework causes. The temporal trend analysis of keywords revealed how the emphasis on specific keywords evolves, providing valuable insights into the dynamic nature of research priorities and emerging areas of interest within the field.

As part of qualitative analysis, thematic network analysis, cluster analysis and thematic evaluation enriched the conceptual framework of construction rework causes by providing depth and context to the identified themes, emphasizing the qualitative nuances and intricacies of the research landscape. Qualitative cluster analysis provided a nuanced and context-rich understanding of the three identified clusters (human- and contractual-based rework causes, design-, quality- and project management-based rework causes, organizational-based rework causes) within rework cause studies, allowing for in-depth exploration of each cluster's qualitative aspects. This framework offers a structured lens to analyze, categorize and discuss various rework causes. By identifying and conceptualizing these clusters, researchers can establish a solid theoretical foundation for future research in construction management. This conceptual contribution is a starting point for further exploration, allowing researchers to delve deeper into each dimension and uncover the complexities.

Thematic evaluation provided a qualitative synthesis of crucial themes, leading to a more comprehensive and context-sensitive interpretation of construction rework causes through in-depth exploration of qualitative data, narratives and perspectives.

6.2 Managerial and practical implications

This study has managerial and practical implications for minimizing construction rework. Architectural engineering and construction companies can use the following managerial and practical implications to make strategies that minimize construction rework.

"Human- and contractual-based rework causes" is one of the origins of construction rework. Practitioners should prioritize the development of clear and comprehensive contracts that explicitly define roles, responsibilities and expectations. Robust contract enforcement mechanisms can help mitigate the risk of rework caused by contractual issues, ensuring that all parties adhere to agreed-upon terms. Managers should focus on human resource management practices, including recruitment, training and skill development. Investing in continuously improving workforce skills and fostering a positive and collaborative work environment can reduce errors and misunderstandings, addressing the human-based causes of rework. Practitioners should conduct a thorough risk assessment at the project initiation

Table 7. Future research directions

Cluster no	Cluster	Future research directions (FRDs)
1	Human- and contractual-based rework causes	1. To concentrate on crafting detailed contracting strategies that tackle construction rework, exploring how different procurement methods and project types impact rework costs and pinpointing responsible parties in construction contracts for rework issues 2. To delve into the human elements contributing to rework, examining behavioral psychology and decision-making processes that result in errors 3. To explore the effectiveness of training programs and initiatives aimed at developing skills to diminish human-induced rework, with a focus on improving competencies and minimizing errors 4. To examine the effectiveness of current contractual structures in handling rework problems and suggest adjustments or new contractual models that encourage minimizing errors 5. To assess how collaborative strategies involving contractors, subcontractors, and clients impact rework reduction, highlighting the significance of communication and problem-solving 6. To study the legal dimensions surrounding rework within contracts, assessing the effectiveness of clauses that assign responsibility for rework and their influence on project results 7. To explore how incorporating technology into contractual agreements (e.g. smart contracts) can resolve conflicts and reduce rework by automating tasks and promoting transparency
2	Design, quality, and project management-based rework causes	8. To investigate the supply chain's involvement in eradicating and minimizing construction rework and defects 9. To investigate the potential of automated technologies in minimizing construction supply chain rework, may offer valuable insights into the obstacles and possibilities of utilizing these technologies to diminish rework 10. To explore the application of artificial neural networks in mapping rework causes and effects within construction projects could offer a more profound comprehension of how rework impacts project performance and productivity 11. To explore innovative methods or tools aimed at streamlining the design process, with a focus on detecting and preventing errors in the early stages to minimize rework in construction phases 12. To investigate sophisticated quality control techniques (like advanced sensors or AI-driven inspections) to improve the precision of construction procedures and diminish rework resulting from quality issues 13. To assess the effectiveness of Integrated Project Delivery methods in reducing rework by promoting collaboration among stakeholders involved in a project from its initiation to its culmination 14. To examine change management protocols and their impact on minimizing rework stemming from design modifications or alterations in scope, emphasizing proactive communication and strategies for adaptation
3	Organizational-based rework causes	15. To study the impact of organizational culture on rework incidents exploring how cultural norms, values, and practices impact rework instances could offer valuable insights toward enhancing project delivery and minimizing rework 16. Perform comparative benchmarking analyses among various organizations to pinpoint optimal approaches in minimizing rework, enabling the wider adoption of effective strategies throughout the industry

Source(s): Authors' own creation

phase, with a specific focus on human- and contractual-based factors. Identifying potential risks early on allows for proactive management and mitigation strategies to be implemented. Implementing systems for continuous monitoring and feedback during the construction process helps practitioners identify issues related to human and contractual aspects in real time. This allows for timely intervention and corrective measures to prevent rework.

Regarding "design-, quality-, and project management-based rework causes," focusing on project planning that includes detailed design reviews, QA protocols and robust project management strategies may prevent rework. Managers should invest in the continuous development of project management skills within their teams. This includes training on effective project planning, scheduling and coordination to minimize the risk of rework associated with project management deficiencies. For practitioners, implementing stringent quality control measures at each stage of the construction process is crucial. Regular inspections and QA checks help ensure that the work meets predefined standards, reducing the chances of rework caused by quality-related issues.

To mitigate the impacts of "organizational-based rework causes", managers should focus on fostering a positive organizational culture that values open communication and collaboration. In addition, establishing a culture of organizational learning and continuous improvement is vital. Regularly analyzing past projects, identifying areas for improvement and implementing corrective measures can contribute to reducing rework caused by organizational deficiencies.

6.3 Limitations and future research directions

The primary contribution of this study lies in providing insights into the research subject and substantially assisting in mitigating future construction rework associated with the three identified origins. Table 7 presents 16 specific directions for future research aimed at minimizing and managing construction rework.

This study had several limitations that warrant future research. First, it exclusively analyzed peer-reviewed articles. Future studies may consider other academic publishing formats, such as book chapters. Second, using data from the WoS database could have constraints. Thus, researchers should explore additional databases, such as Science Direct or Scopus. Third, this study assessed rework causes in superstructure construction but excluded those related to infrastructures and substructures. Rework causes in substructures differ from those in superstructures, highlighting a potential avenue for future research. Moreover, future bibliometric investigations could explore rework costs and impacts.

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