

A Comprehensive Bibliometric Analysis of Material Cost Escalation in Building Construction

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Abstract

Rising costs of construction materials, particularly steel, concrete, and other materials, have become a huge international issue, as they have affected the budgets of the project and its viability as well as its affordability. The recent inflation, supply-chain turmoil, and political unrest are increasing the cost volatility, and escalating material prices have become the focus of construction research. The Dimensions AI database was used to conduct a bibliometric analysis (2002-2025). A specific search query has been used to obtain literature on cost increases, price fluctuations, and construction materials. After data cleaning, VOSviewer provided the possibility to analyze the trends of publications, performance on citations, the largest institutions, journals, and clusters of keywords. Publication trends showed substantial research growth after 2012, with Nigeria, China, Malaysia, and India emerging as major contributing countries, while leading institutional and journal contributions were associated with Hanyang University, Obafemi Awolowo University, the International Journal of Project Management, and the Journal of Construction Engineering and Management. Network measures pointed out common themes and patterns of research. Two large clusters were identified: (1) a problem-focused cluster centered on cost, overrun, risk, and time; and (2) a solution-focused cluster emphasizing strategy, knowledge, tools, and implementation. To enhance analytical depth, a temporal burst analysis was performed using document-level bigram extraction and structure break detection (PELT algorithm) in RStudio. Results reveal a structural shift around 2012 toward intensified project-level cost overrun research, followed by post-2023 acceleration in governance and digital-oriented themes such as stakeholder collaboration and BIM-based approaches, highlighting evolving mitigation strategies for cost volatility.

Keywords: Bibliometric Analysis, Construction Materials, Cost Escalation, Material Price Volatility, Risk Management.

1. Introduction

The study on cost escalation on certain construction materials such as steel, concrete, and lumber building projects has become an important area of interest as its influence affects a lot of the construction budgets and project feasibility. Price increases in the past few years have been a problem in the world due to disruptions in the supply chain, inflation, and geopolitical uncertainties and instabilities [1],[2]. Material costs, steel, and concrete prices have become volatile as never before in the construction industry since the beginning of the 2000s [3–6]. The trend also has a practical implication on housing affordability, the development of infrastructure, and the sustainability of the entire economy [7]. Research has also reported that material costs might consume up to 60% of the project costs, which emphasizes the necessity to comprehend and control the price increases [1],[2],[8].

Even though numerous studies have been conducted on construction cost escalation and overruns, there is still a gap in knowledge about the subtle impacts of inflation on prices for specific materials like steel, concrete, and lumber, particularly when the market situation is unpredictable [3],[9],[10]. Whereas a few articles are devoted to predictive approaches to material prices [11],[12]. Many articles dwell on contractual and risk

management strategies [13],[14]. The sufficiency of existing escalation terms, as well as methods of forecasting, is said to determine whether classical estimation techniques adequately reflect the volatility of a market or not [15],[16]. Besides, socio-economic impacts of inflation of material costs, such as decreased housing affordability and project delays, are also studied seldom within integrated frameworks [17]. Simultaneously, there are research gaps in the integrated scholarship on material-specific escalation in uncertain markets [18],[19] and the sufficiency of the escalation provisions and prediction tools is subject to controversy [20–22].

This study builds on previous bibliometric research, using traditional science-mapping approaches in conjunction with temporal burst analysis using a structural break detection method. This method has the advantage over previous studies, which are mainly descriptive of trends, to identify where and when priorities change in the research. As well, the research provides a contribution by categorizing literature into problem and solution research streams and by recognizing new emerging research streams, including digital cost management and stakeholder collaboration. The contributions offer theoretical progress in understanding the evolution of research as well as practical insights for improving cost management strategies in construction projects.

2. Methodology

The current studies of construction material cost escalation are quite fragmented as they carry various areas of study, which include predictive price modeling, contractual mechanisms, risk management, and supply chain research. The traditional narrative reviews or single-method empirical research is not able to unify such scattered knowledge and to describe long-term structural and temporal changes in the sphere. The use of a bibliometric method is especially suitable in this case, as it allows mapping intellectual frameworks systematically, defining the dominant and emerging themes, and identifying changes in the research focus over time. This paper integrates systematic screening, metrics of performance, co-occurrence analysis of keywords, and burst detection to transform bibliometric trends into analysis facts that depict how and why the research on material cost escalation has changed over the years. Moreover, document-level temporal burst analysis based on bigram extraction and structural break detection (PELT algorithm) to find statistically significant inflection points and measure the change in the thematic acceleration with time was performed in R. This paper used a bibliometric analysis (2002–2025) to find out the scientific environment within the context of material cost escalation in building and housing projects.

2.1 Data Base Used

The data were obtained through Dimensions AI, which was selected based on the overall coverage of scholarly output and citation data and analytical metadata around the world [23–26]. The search strategy was structured, and a predetermined query stream was used to ensure that all relevant documents were retrieved (<https://www.dimensions.ai/>). The bibliographic data were extracted from the database on 15 November 2025.

2.2 Search Query

“material cost escalation” OR “material price escalation” OR “construction material prices” OR “construction cost escalation” OR “cost overrun” OR “price volatility” OR “building materials cost” OR “Building construction inflation” OR “Building project cost increase”) AND (“building projects” OR “housing projects”)

Total records retrieved from the database -260

Total records remaining after applying the search conditions - 36

2.3 Inclusion and Exclusion Criteria

Table 1 shows selection criteria for articles. A structured inclusion–exclusion framework was adopted to ensure the quality and relevance of the dataset. Initially, 260 peer-reviewed journal articles were retrieved using the predefined search query. Automated filtering based on publication year (2002–2025) reduced the dataset to 256 records. Further filtering to include only UGC Group II indexed journals resulted in 221 records. Subsequently, manual screening of titles and abstracts was conducted to assess relevance, leading to the exclusion of out-of-scope and non-empirical studies and yielding a final dataset of 36 articles for detailed analysis. While data filtering and preprocessing steps were supported through database queries and spreadsheet operations, the relevance assessment and final selection were performed manually to ensure contextual accuracy. Exported records were then cleaned to remove duplicates and filtered the titles, abstract, and author keys to remove irrelevant records saved in CSV. The VOS viewer was used to analyze the final dataset; this program is a specialized tool that can be used to map out bibliometrics. The criteria for choosing journals under UGC Group II were such that the peer-reviewed journals with quality control and academic recognition are included. The filtering process helps build the most reliable dataset possible because sources that are not indexed or of poor quality are filtered out, further improving the credibility and consistency of the bibliometric analysis.

The bibliometric analysis is used as the main research method in this study to investigate the evolution of the research literature and its thematic analysis concerning material cost escalation. To ensure data quality, a systematic literature search technique was used, which included structured inclusion–exclusion criteria and predefined search queries, comparable to the PRISMA filter. An additional advanced temporal burst analysis was also done based on the PELT algorithm to identify structural changes and new trends in the research field over time. This methodological package allows for static mapping as well as dynamic analysis of the evolution of research.

Table 1 Criteria for selection of article

Criteria	Inclusion	Exclusion
Type of Literature	Peer-reviewed journal research articles (n=260)	Books, book chapters, book series, conference proceedings, preprints, monographs
Time Frame	Publications from 2002 to 2025 (n=256 Articles)	Publications prior to 2001 (n=4 Removed)
Journal List	Journals indexed under UGC Journal Group II (n=221)	Journals outside UGC Journal Group II (n=35 Removed)
Subject Area	Included in review (n = 36)	Reports excluded: Not Based on Empirical Data (n = 70) Focusing on other area (n = 55) Out of study Scope (n = 60)

3. Literature Review

The rising costs of construction materials have become one of the most critical concerns in the global construction industry because of their direct influence on project feasibility, contractor profitability, housing affordability, schedule performance, and infrastructure sustainability [27]. The increasing volatility in the prices of steel, cement, concrete, timber, fuel, and labor has intensified after major global disruptions such as inflationary pressures, supply-chain interruptions, economic crises, and geopolitical instability [28],[29]. The shortlisted studies were examined from various angles, such as project overruns, inflation, forecasting models, contractual mechanisms, housing affordability, risk management, and digital forecasting systems [30–33].

A number of studies examined the correlation between material-related issues and project delays and cost overruns. Khursheed et al. [1] investigated the delays and budget overruns due to material-related factors and found that unstable material supply and fluctuation in material prices significantly impact project delivery and contractor performance. Borse and Khare [5] studied the cost and schedule overruns in construction projects and found that escalation in labor as well as material costs plays a significant role in the project delay and uncertainty. The improper planning, unstable procurement systems, and varying material costs were also found to be the significant reasons for the time and cost overruns in construction projects by Mulla and Waghmare [6]. Similarly, unstable procurement systems, volatile material costs, and improper planning emerged as major contributors to time and cost overruns for construction projects.

The study [34] has found that inflation, fluctuation of exchange rates, dependency on imported food, high fuel prices, and taxation policies are responsible for high price volatilities in developing countries. The same results were observed in the Ethiopian study [17], in which inflation, limited foreign currency, unstable procurement systems, and inefficiencies of the supply chain were cited as main factors contributing to project cost overrun. The Sri Lankan research study on the impact of economic crises on the prices of building construction materials also showed that economic crises, import control, and depreciation of the currency had significant impacts on the prices of steel, cement, and fuel, which consequently had significant negative impacts on the project delivery and the stability of the contractors [18].

A study of housing affordability found that an increase in the price of construction materials has a significant impact on sustainable housing development. Shaposhnikova [2], studied how rising construction material costs affect housing affordability and found that post-pandemic material inflation and supply shortages had a significant effect on housing price inflation and affordability. In a South African study [27], it was reported that a rise in the cost of construction materials harms affordable housing delivery, maintenance costs, and satisfaction

of stakeholders. The study found that material inflation has a direct impact on the sustainability of affordable housing projects in the long term [35–37].

Several studies concentrated on escalation clauses and contractual risk management practices. [13] critically examined the sufficiency of contractual provisions in Indian construction contracts and observed that fixed-price contracts transfer excessive escalation risk to contractors during volatile market conditions. The study also evaluated CPWD Clause 10CC and concluded that existing escalation clauses often fail to adequately compensate contractors during periods of severe inflation. Similar conclusions were reported in studies discussing clauses for material cost escalation, BOT project risks, and infrastructure contracts, where improper allocation of escalation risk resulted in disputes, contractor losses, and compromised project performance.

The other important research area from the shortlisted literature was forecasting and predictive modeling approaches [30–32]. The study [38] used the ARIMA and Box–Jenkins models to predict the prices of steel, cement, and concrete and claimed that the prediction performance of this method is better than the traditional prediction method. The study [39], showed that the machine-learning-based forecasting models can enhance the short-term escalation prediction in the volatile markets. Another study on interval forecasting using neural networks explained that the neural network and hybrid machine-learning methods are effective at dealing with uncertainty and nonlinearity for forecasting construction material prices [11].

The systematic literature review (SLR) of the price forecasting techniques resulted in the fact that in construction economics research, many people are using machine learning models like ANN, GRNN, LSTM, LS-SVM, Random Forest, and hybrid ARIMA-NARNET models [16],[40]. Studies forecasting cement, asphalt, steel, aggregate, labor, and house prices showed that intelligent forecasting systems outperform traditional regression-based approaches under uncertain economic conditions. The literature further indicated that after 2016 there was a rapid increase in publications related to AI-driven construction forecasting because of the growing complexity of construction markets and availability of large datasets [41].

The link between material management, construction waste, and escalated project costs was also investigated [42]. The poor management of materials has created a major increase in construction expenditure and loss of productivity [43]. In the same way, it has been found that material inefficiency, due to inefficient use of materials, causes both economic loss and environmental inefficiency in studies of construction waste management [44].

The short-listed studies also emphasized the increasing relevance of risk management and digital technologies in the mitigation of escalation [21],[22].. Under highly volatile markets, escalation forecasting accuracy and preparedness for projects could be

enhanced by AI-based forecasting systems, neural network models, and approaches based on machine learning [11],[41].

The overall literature shows that the escalation of construction material costs can be looked upon as a multidimensional issue that includes inflation, procurement inefficiencies, disruption in supply chains, inadequate contracts, uncertainty in forecasts, and housing affordability issues. The literature is still divided into forecasting models, contractual mechanisms, macroeconomic analysis, and project-performance studies, although the shortlisted studies offer interesting insights into individual elements of escalation. In addition, there is a lack of research that has systematically tracked the evolution and time transformation of research on material cost escalation over time. Therefore, the present study addresses these limitations through a comprehensive bibliometric and temporal burst analysis of research on the escalation of construction material costs between 2002 and 2025.

4. Bibliometric analysis results

4.1 Top Cited Article

Material-related risks, procurement inefficiencies, inflation pressure, and supply chain disruptions were among the highlighted influential factors in the highly

cited studies related to construction project performance. The earlier research focused on the role of resource limitation, material fluctuation, and managerial inefficiency in the escalation of project cost and financial imbalance in building projects. Later research continued this dialogue and introduced new analysis techniques, including fuzzy assessment, system dynamics, artificial intelligence, and forecasting models based on machine learning, to analyze construction material price volatility, escalation risk, and forecasting in cost management. The citations also suggest that there is a growing interest in the recent literature in material cost forecasting, risk management with sensitivity to escalation, supply-chain resilience, and development of data-driven decision-support systems for enhancing cost predictability and financial sustainability in construction projects. The whole distribution of citations indicates that most studies generated low-level scholarly impact, while very few studies generated high-level scholarly impact. In particular, 1 paper had more than 300 citations, 1 paper had 201–300 citations, 5 papers had 101–200 citations, 14 papers had 51–100 citations, and 18 papers had 26–50 citations. The rest of the publications have been cited 25 times or less, suggesting that material cost escalation research is a growth and emerging research field with a relatively focused intellectual nucleus. **Table 2** shows all cited details.

Table 2 Highly cited study

Rank	Title	Source title	Pub Year	Authors Citations	Times cited
1	“The effects of construction delays on project delivery in Nigerian construction industry”	“International Journal of Project Management”	2002	[45]	339
2	“A fuzzy synthetic evaluation approach for risk assessment: a case of Singapore's green projects”	“Journal of Cleaner Production”	2016	[46]	239
3	“A system dynamics model for assessing the impacts of design errors in construction projects”	“Mathematical and Computer Modelling”	2013	[47]	131
4	“Analysing delay causes and effects in Ghanaian state housing construction projects”	“International Journal of Managing Projects in Business”	2015	[48]	128
5	“Supply Chain Management for Prefabricated Building Projects in Hong Kong”	“Journal of Management in Engineering”	2020	[49]	121
6	“A knowledge-based risk mapping tool for cost estimation of international construction projects”	“Automation in Construction”	2014	[50]	108
7	Time Delay and Cost Overrun in Qatari Public Construction Projects	“Procedia Engineering”	2016	[51]	107
8	“Impact of environmental factors on building project performance in Delta State, Nigeria”	“HBRC Journal”	2015	[52]	89
9	“Investigating design changes in Malaysian building projects”	“Architectural Engineering and Design Management”	2017	[53]	86
10	“Machine learning-aided engineering services' cost overruns prediction in high-rise residential building projects: Application of random forest regression”	“Journal of Building Engineering”	2022	[54]	85

4.2 Leading Organization

The institutional environment shown in **Table 3** indicates a heterogeneous blend of universities that engage in research, and Obafemi Awolowo University can be the most effective again, although it generates fewer papers, with an outstanding average of 91.5 citations per article. Conversely, Hanyang University and Tun Hussein Onn University of Malaysia have the highest volumes of publications but were less focused with a lesser impact on average. Such universities as the University of Johannesburg, the Federal University of Technology, and the Universiti Tunku Abdul Rahman have high mid-range impact in terms of continuity in research and significant scholarly impact. Otherwise, regional perspectives are provided by the Islamic University of Indonesia, the

University of Sharjah, and the University of the West Indies at Saint Augustine, although with smaller citation footprints. **Figure 1** illustrates the distribution of research across countries, highlighting the dominance of emerging economies. Each node in **Figure 1** is a university, and the size of the nodes and labels reflects the number of publications and the impact of citations. The connecting lines indicate collaborative relationships between institutions: thicker lines indicate higher intensity of collaboration. Closer relationships between nodes (close in distance) represent closer collaboration or thematic relationships. The various colors denote the different institutional collaboration clusters found through the VOSviewer clustering algorithm.

Table 3 Top Contributing Academic Institutions

Rank	Organization	Publication	Citations	Average Citations / Article
1	Hanyang University	5	86	17.20
2	Tun Hussein Onn University of Malaysia	5	55	11.00
3	Obafemi Awolowo University	4	366	91.50
4	University of Johannesburg	4	104	26.00
5	Federal University of Technology	3	104	34.67
6	Islamic University of Indonesia	3	22	7.33
7	Liverpool John Moores University	3	42	14.00
8	Universiti Tunku Abdul Rahman	3	110	36.67
9	University of Sharjah	3	26	8.67
10	University of The West Indies at Saint Augustine	3	20	6.67
11	king saud university	2	85	42.50
12	National University of Singapore	2	304	152.00
13	University of South Australia	2	165	82.50

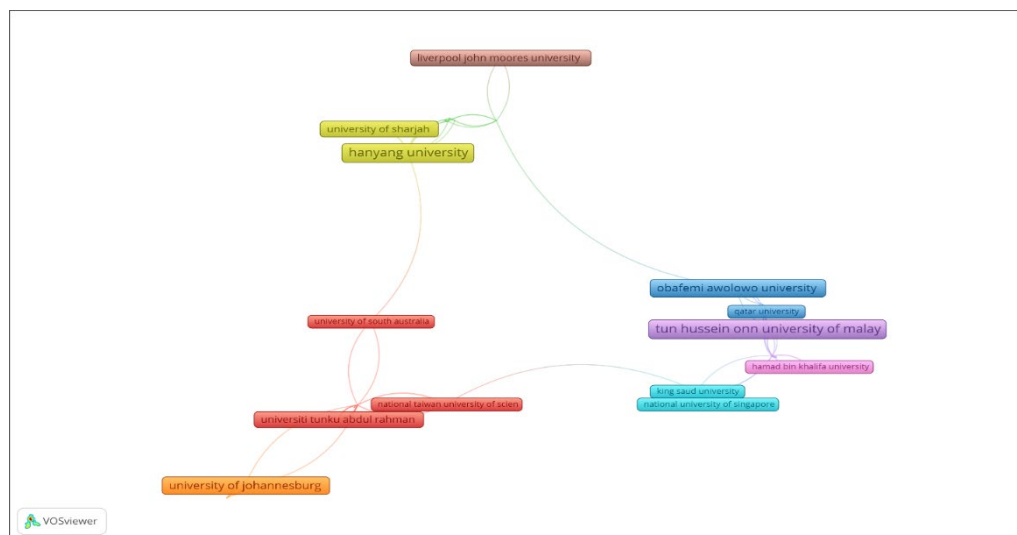


Figure 1 Top Organization (VOS viewer)

4.3 Country

The distribution of publications on material cost escalation in building construction is given in **Table 4**, country-wise. Nigeria had the highest count of documents (18), showing that there is strong research interest in issues of building material price fluctuations, cost overruns, and project affordability in developing economies. China and Malaysia had the next highest number of publications, with

13 each, reflecting a growing interest in research about infrastructure development, supply-chain issues, and construction cost management. India and Indonesia had also shown substantial scholarly contributions, with 12 publications each, highlighting the role of managing fluctuations in the price of materials in fast-urbanizing economies. The United States, the United Kingdom, and South Africa had ten publications each,

reflecting both emerging and developed economy perspectives on construction material escalation and project cost control. Moreover, South Korea and Egypt

demonstrate the geographical dispersion of research interests in material cost escalation and construction cost management.

Table 4 Top 10 Leading Countries

country	Nigeria	China	Malaysia	India	Indonesia	South Africa	United Kingdom	United States	South Korea	Egypt
documents	18	13	13	12	12	10	10	10	9	8

4.4 Top Journals

This journal environment in **Table 5** is characterized by high levels of concentration of influential research in the high-impact, Q1-ranked journals, with the International Journal of Project Management taking a leading position (albeit with only one document) with 339 citations, indicating that it represents the best environment to conduct fundamental project-performance research. Journal of Construction Engineering and Management comes in with six documents and 261 citations, which indicate its consistent performance and placement in the engineering-oriented scholarly circles. The Journal of Cleaner Production and Automation of Elsevier has also demonstrated significant impact, evidenced by high H-index values, substantial citation numbers, and some of the highest SJR records in the dataset, particularly due to its

focus on interdisciplinary research that includes sustainability and technological innovation. In the meantime, Buildings has the greatest number of documents (10), and its contribution is wider in terms of publication volume with a moderate influence on citation and is a convenient platform of emerging and regionally based construction research. The distribution of major journals contributing to research on escalating material costs is given in **Figure 2**. The maximum number of journals are of the Q1 type. High-impact journals have high citation influence, and other journals contribute through high publications. Larger nodes are journals with higher publication and citation impacts and links, and shorter distances are stronger bibliographic relationships. The colors denote journal clusters obtained by the clustering algorithm implemented in VOSviewer.

Table 5 Major publication outlets

Rank	Journal	Document	Citations	Publisher	H Index	SJR 2024
1	International Journal of Project Management	1	339	Elsevier B.V.	190	1.870 (Q1)
2	Journal of Construction Engineering and Management	6	261	ASCE	147	1.113 (Q1)
3	Journal of Cleaner Production	1	239	Elsevier B.V.	354	2.174 (Q1)
4	Automation in Construction	3	164	Elsevier B.V.	200	2.890 (Q1)
5	Buildings	10	150	MDPI	71	0.652 (Q1)

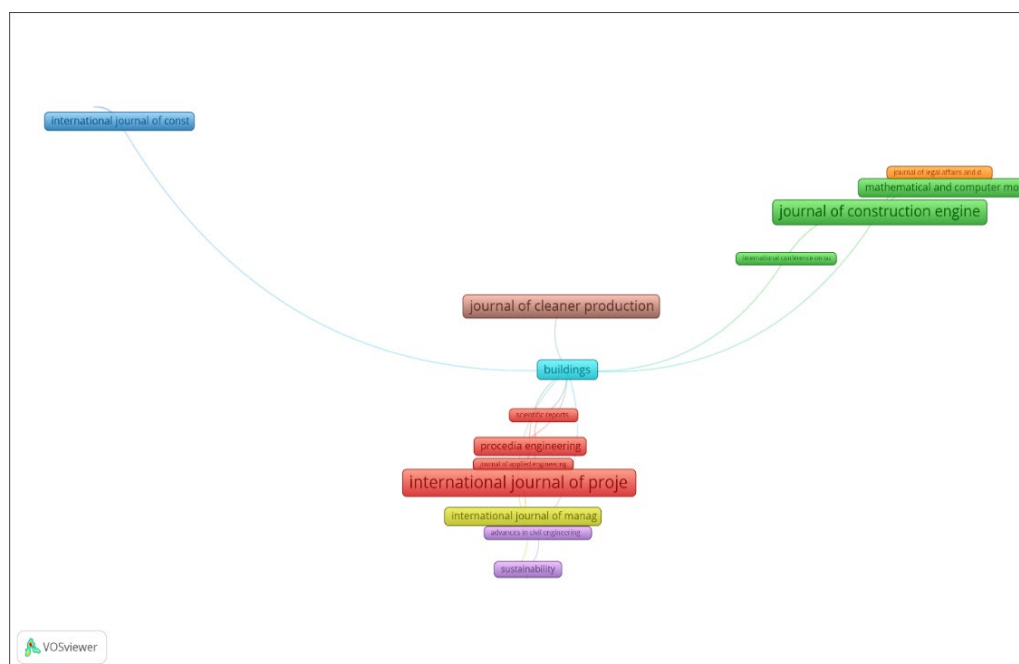


Figure 2 High Impact Journals (VOS viewer)

4.5 Key Words Analysis

The keywords were extracted from the titles and abstracts of the articles, as well as the author keywords, with the help of VOSviewer software. The occurrence frequency of the top 15 keywords was selected after the preprocessing and generic terms were removed for co-occurrence analysis. Link strength is defined as the number of times keywords are co-occurring, while relevance score is the thematic relevance of a keyword within the network. Conceptual density refers to the extent to which the themes are related within a cluster. We used the co-occurrence relationship of keywords to automatically cluster related keywords in VOSviewer and manually interpreted the clustered keywords and named them by their dominant research themes.

The two-cluster configuration was selected based on link strength and conceptual density to represent a macroevolution from diagnostic cost-overrun studies to strategy- and solution-oriented research. The two-cluster solution was explored in VOSviewer and chosen for both methodological reasons and interpretative reasons. While higher-order clustering solutions were produced in preliminary analysis, these solutions also created disjointed micro-clusters with overlapping themes and poor conceptual clarity. The distinction between the two-cluster configuration was, however, clear and meaningful, distinguishing between problem-oriented and solution-oriented research streams. This analytical simplicity and thematic interpretability enabled a more powerful representation of the intellectual structure and the evolution of research on material cost escalation.

Based on the dominant patterns of keyword co-occurrence and the thematic emphasis of the papers, and

based on the conceptual proximity of the papers in the network as identified by VOSviewer, the 36 included papers were mapped onto the identified clusters. The problem-oriented cluster was mostly linked to studies addressing cost overruns, escalation risk, contractor issues, delays, and project performance, while the solution-oriented cluster was mostly related to studies addressing forecasting models, BIM integration, digital cost management, stakeholder collaboration, and mitigation strategies. Given that there were multiple papers that discussed aspects of material cost escalation in a multidimensional way, there were some papers that showed overlap between the clusters, indicating the interdisciplinary nature of the research domain. For better analysis reliability, the automated clustering obtained from VOSviewer was manually checked by examining the titles, abstracts, and study objectives of the papers included and ensuring that the concept of the papers matched with the clustering result.

Each node in **Figure 3** is a material cost escalation research-related keyword, and the larger the node size, the more often the keyword appears in the set. The lines connecting the keywords show co-occurrence relationships, with thicker lines denoting stronger thematic relationships. The closer the nodes are to each other, the more similar the concepts of the respective keywords. The various colors represent the different thematic clusters obtained via the VOSviewer clustering algorithm. The figure is advantageous because it provides a visual representation of the intellectual structure, thematic relationships, and dominant research areas in the field, in addition to the numeric values in the table.

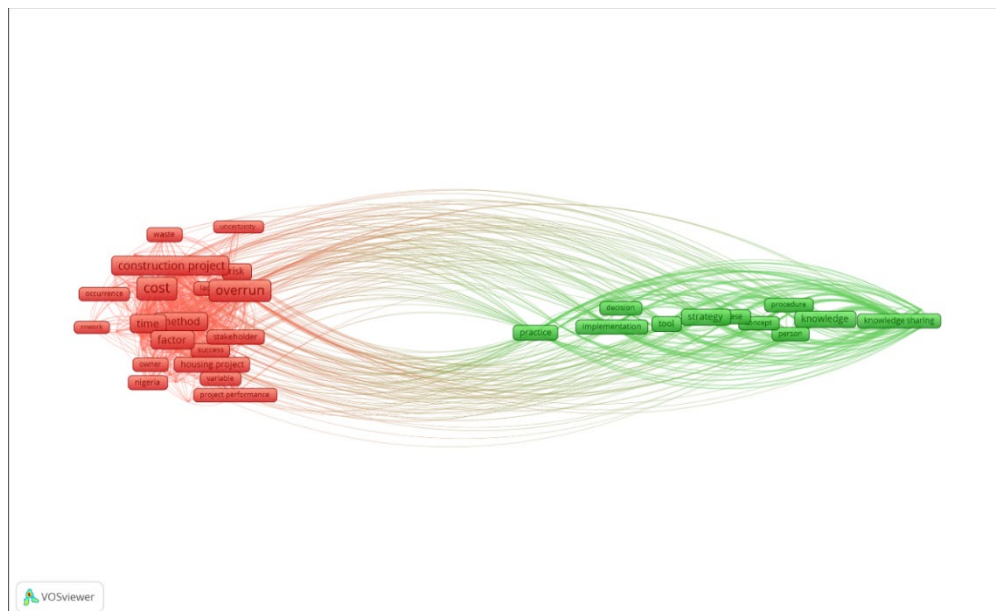


Figure 3 Cluster (VOS viewer)

Cluster 1 (Red) focuses on the main operational issues of the construction project delivery with cost, escalation, construction project, risk, time, and factor as the predominant keywords that have been used in the research

stream that is widely involved in diagnosing what causes and what happens as a result of a project failing to perform as expected. This cluster encapsulates such themes as delays, rework, uncertainty, and issues related to the

stakeholders—a more definitive factor that determines the dependability of the schedule and the stability of the budget, at least in the case of rising developing countries. Conversely, Cluster 2 (Green) is more future-focused, solutions-driven research that is based on knowledge, strategy, implementation, practice, and tools. This group focuses on managerial innovation, decision support, and knowledge-sharing mechanisms that can assist organizations to enhance project results. Combined, the two clusters depict an apparent thematic flow:

These statistics indicate clearly that Cluster 1 has operational problem-centric terms whose occurrence and link-strength values are very high, namely, Cost (435 occurrences, 8,394 link strength) and Overrun (413, 8,044) dominate as the key problem determinants of construction-

project failure, followed by Time (208, 4,350), Risk (134, 2,474), and Contractor (129, 2,780), which somewhat is the impact of. Conversely, Cluster 2 is closer to capability-building and organizational improvement with Strategy (119 occurrences, 6,007 link strength) and Knowledge (although slightly less common, 114 occurrences) showing an extremely high link strength of 8,250, which indicates that they are instrumental in connecting and enabling solutions across the network. All these values present a distinct sequence: the diagnosis of cost-time-risk issues in the context of construction research is first performed, followed by transition into knowledge-based strategic frames reinforcing the process of decision-making and long-term performance. **Table 6** shows the mapping of both clusters.

Table 6 Keyword mapping

Sr. No	Cluster	Term	Occurrences	Relevance Score	Total Link strength
1	1	Cost	435	0.8346	8394
2	1	Overrun	413	0.5515	8044
3	1	Building Project	233	0.7864	4629
4	1	Construction Project	231	0.8278	7311
5	1	Factor	226	0.8814	4712
6	1	Time	208	0.94	4350
7	1	Impact	142	0.7786	2921
8	1	Construction	136	0.8642	2451
9	1	Risk	134	0.6619	2474
10	1	Contractor	129	0.9555	2780
11	2	Strategy	119	1.0634	6007
12	1	Building	115	0.7984	2149
13	2	Knowledge	114	1.6656	8250
14	1	Cause	103	0.8824	2105
15	1	Performance	99	0.8155	2261

4.6 Discussion and Interpretation

Research themes have strong linkages to global economic and industrial disruptions. The shift in studies to cost escalation and project performance post-2012 can be attributed to the long-term effects of the global financial crisis, and the recent focus on collaboration and digital solutions has been driven by the challenges of the COVID-19 pandemic and the continuing disruption of the supply chain. Furthermore, the high volume of risk-related keywords underlines the importance of risk management as an integral part of handling uncertainty, cost fluctuations, and delivery issues in today's construction context.

The keywords in Cluster 1—cost, overrun, construction project, time, risk, and contractor—along with the early temporal acceleration of themes such as complex building and building projects, suggest that the earlier phase of scholarship was mainly diagnostic. Initial research focused primarily on the identification of performance issues, risk of escalation, and delays and inefficiencies in the operation of projects in volatile material market conditions, with the latter moves toward collaborative and digital mitigation strategies.

4.6.1 Practical Implications for Engineering Practice

This study's results are relevant to engineering practice. The shift from problem-oriented research (cost escalation, delays, and risk) to solution-oriented approaches (strategy, knowledge systems, and digital tools) underscores the critical need for proactive cost management in construction projects. This will help practitioners to enhance cost forecasting, integrate risk-based planning strategies, and leverage the use of digital tools like BIM for real-time cost monitoring. Further, the growing focus on stakeholders' collaboration means that an integrated model of decision-making is likely to increase project resilience in the context of volatile material prices.

In particular, material cost escalation, revealed the results, is a highly concerning material/price change in the projects, leading to the emergence of cost, overrun, time, and risk as dominant inter-connected factors. These terms have a high frequency of occurrence, and are strongly associated with other terms, suggesting that the problem of material cost escalation is tightly coupled to other issues, such as delays and contractor-related issues, that reduce overall project efficiency. Temporal burst analysis also shows that the theme of cost overrun(s) has been continuously growing throughout the timeline to the

current years and has reached its highest prominence, suggesting that material-driven cost instability has been a research focus over the years. Furthermore, the increased interest in the collaboration between stakeholders and BIM based solutions indicate a trend where material cost escalation is being controlled using digital tools, coordination and proactive planning strategies.

5. Temporal Burst Analysis

Although traditional bibliometric measurements including the number of publications and citation rates help to show the structural configuration of the research area, they can hardly tell us about the dynamics of thematic development in time. To overcome this weakness and determine when, how intensively, and why changes in research focus took place, a temporal burst analysis was conducted using the R statistical environment (RStudio) to ensure reproducibility and methodological transparency. Bibliographic information, exported from the Dimensions database, was preprocessed using the dplyr, tidytext, tidyr, and stringr packages. Bigrams were extracted at the document level from the titles and abstracts of articles to

prevent repetition bias, while citation artifacts were removed during text cleaning. Yearly document-level frequencies of occurrence were computed for each term, and detection of structural breaks was performed with the changepoint package (PELT algorithm) to determine significant inflection points of thematic intensity through time. A stabilized burst strength index was then calculated by comparing post-shift peak frequency to that of the pre-shift baseline average. This way, it was possible to identify temporally accelerating research themes without losing conceptual and statistical robustness. The “Peak Frequency” in **Table 7** is the highest yearly occurrence of the corresponding bigram term obtained from the titles and abstracts (after pre-processing and text cleaning). Unlike the number of unique documents, the temporal burst analysis is based on the occurrence patterns of terms over time and uses these patterns to measure the intensity of the themes. For consistency between the graphical visualization and the tabular results of the burst analysis, the y-axis labels of **Figures 4–7** were therefore changed to “Term Frequency”. The burst output from the program after removing unwanted terms is shown in **Table 7**.

Table 7 Burst Detection Results

Rank	Term	Peak Year	Peak Frequency	Structural Shift Year	Burst Strength Index
1	Complex building	2013	25	2012	25
2	Building projects	2013	29	2012	23.38
3	Cost overrun(s)	2023	24	2012	20.67
4	Construction projects	2019	15	2012	13.86
5	Stakeholder collaboration	2025	12	2023	12
6	BIM based	2025	13	2024	11.37
7	Construction readiness	2025	11	2024	11

Figure 4 displays the temporal burst intensity of the most advanced research themes that resulted from the structural break analysis. The results show a clear thematic inflection starting in about 2012, which represents a transition to more intense investigations on a project basis. Complex building (Peak Year: 2013; Burst Index: 25) and building projects (Peak Year: 2013; Burst Index: 23.38) show the earliest and strongest acceleration, which is a rapid growth of empirical research aiming to examine

project complexity and implementation contexts in the early growth period of the field. The structural change in 2012 can also be associated with research attention that was paid to cost overrun and project performance after the global financial crisis and the recession. Disruptions from the COVID-19 pandemic have been more recent trends, with increased interest in resilient and digital cost management.

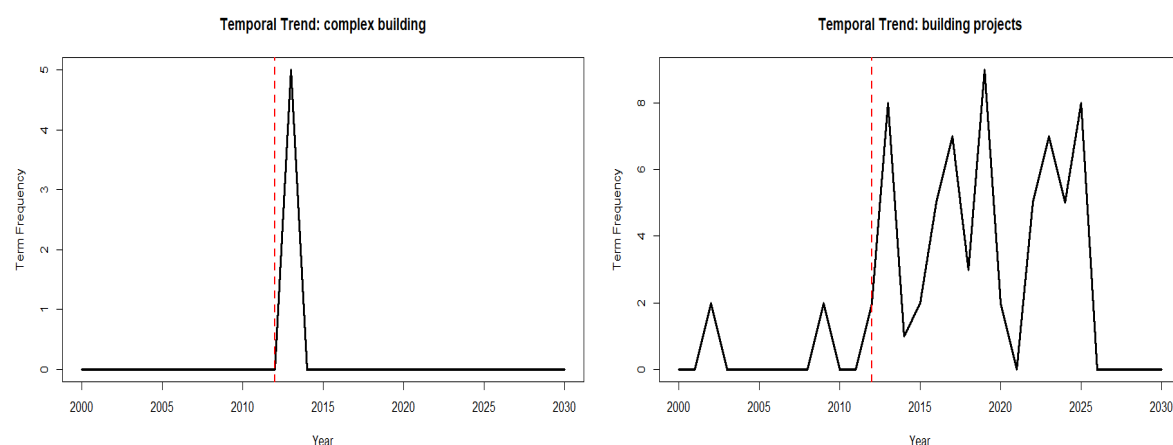


Figure 4 Complex building and Building Project (R Studio-Output)

Figure 5 shows that theme cost overrun(s) show sustained and later intensification with a burst strength index of 20.67 in 2023, which confirms that cost performance is a dominant and evolving research concern. Similarly, construction projects (peak year: 2019; burst index: 13.86) are a consolidation of project-scale analytical focus after the 2012 structural shift.

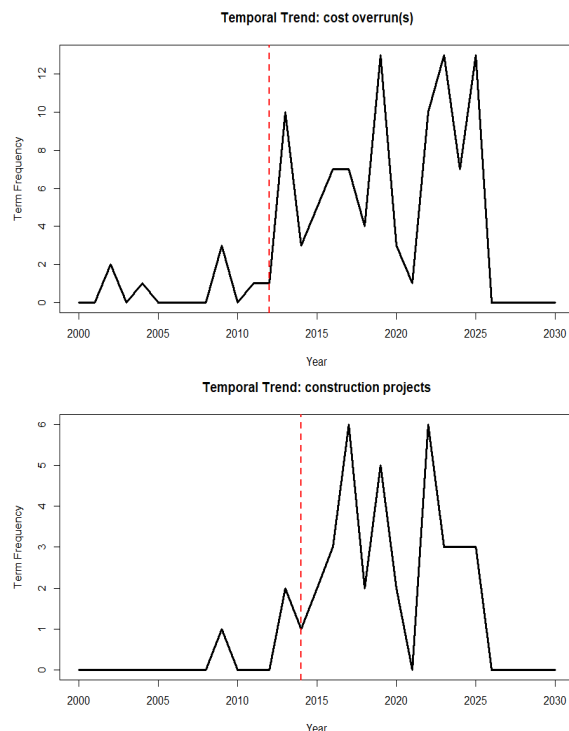


Figure 5 Cost overruns and Construction projects (R Studio-Output)

Figure 6 displays a more recent thematic acceleration in stakeholder collaboration (Shift: 2023) and BIM-based approaches (Shift: 2024), while

Figure 7 shows Construction readiness (Shift: 2024) points to an emerging shift to governance-oriented and digital mitigation strategies. Together, the table illustrates a series of developments from an initial complexity-focused project study through to an increased level of cost overrun research and then to a modern focus on collaborative and digital structures to enhance resilience in cost performance.

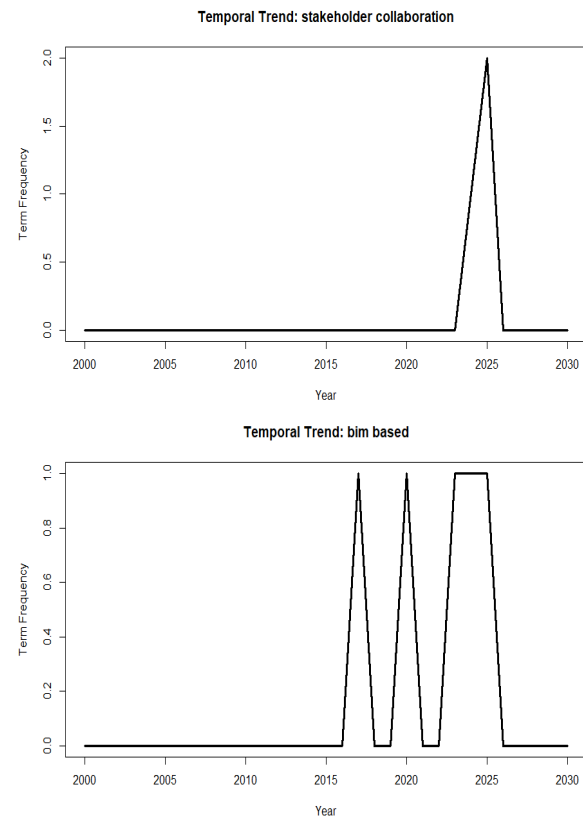


Figure 6 Stakeholder collaboration and BIM-based (R Studio-Output)

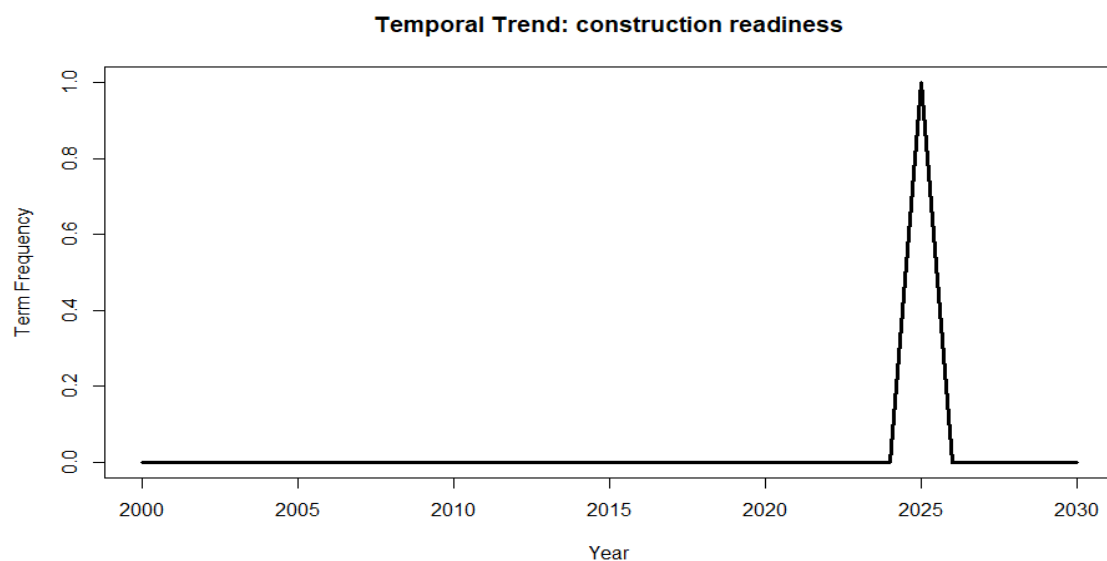


Figure 7 Construction readiness (R Studio-Output)

5.1 Identification of Declining Research Themes

An extra **Table 8** with decreasing or vanishing research themes was added for a complementary temporal perspective. Several themes related to earlier project-oriented and conventional research that had less recent temporal intensity were further identified.

Table 8 Declining or Fading Research Themes Based on Temporal Frequency Analysis

Rank	Declining Theme	Early Period Average	Recent Period Average	Decline Score
1	Construction companies	5.00	1.00	4.00
2	Empirical data	5.00	1.00	4.00
3	Project actors	5.00	1.00	4.00
4	Project based	5.00	1.00	4.00
5	Proposed model	5.00	1.00	4.00
6	Building information	5.00	1.67	3.33
7	Building process	3.00	1.00	2.00
8	Data analysis	3.00	1.00	2.00
9	Project managers	2.50	1.33	1.17
10	Data collected	2.00	1.00	1.00
11	Inferential statistics	2.00	1.00	1.00
12	Project management	1.80	1.00	0.80
13	Cost estimation	1.50	1.00	0.50
14	Importance index	2.00	1.50	0.50

5.2 Integration of Temporal Burst Themes with Keyword Clusters

In addition, temporal burst analysis results were combined with the keyword-cluster results by mapping the keyword burst themes to the two large clusters of keywords derived from the co-occurrence network using VOSviewer. Cost-related, risk-related, time-related, and project-performance-related issues were strongly correlated with themes that emerged early in the dataset, such as cost, complex building, building projects, and construction projects. On the other hand, the shift towards stakeholder collaboration, BIM-based approaches, and construction readiness are very much in line with the solution-oriented cluster focused on strategy, knowledge, and implementation and digital management approaches. This integration reflects the thematic development of the field, from diagnostic investigation to collaborative and technology-based mitigation strategies to address the cost escalation of materials.

6. Future Research Direction

The proposed future research directions in the given study are clearly based on the bibliometric results of the

analysis of the keywords, clusters, and temporal bursts. Cluster 1 is dominated by terms that are of a problem nature, indicating that more integrated models are still required to reflect interactions between cost, time, and risk. At the same time, the robust surge in 2023 of expressions related to collaborative and digital frameworks, as well as price volatility, indicates that a new research direction should focus on digital, predictive, and strategy-based escalation management. Based on these observed thematic and temporal patterns, the following research directions are thus developed as a direct result of these trends and not as a result of some generic gaps that were observed in earlier literature.

This study's bibliometric results, keyword-cluster structure, and temporal burst patterns are the basis for the proposed future research directions. The overwhelming presence of Cluster 1 keywords, e.g., cost, overrun, risk, time, and contractor, suggests that the focus of the research is still heavily on the diagnosis of project-performance problems stemming from material price volatility. At the same time, temporal spikes in stakeholder collaboration, BIM-based approaches, and construction readiness since 2023 show a shift toward governance-oriented, predictive, and digital mitigation frameworks. All these findings indicate that future research needs to shift from the identification of the single factors to integrated, technology-supported escalation management systems that focus on resilience and consider complex interactions between inflation, supply-chain instability, procurement uncertainty, and project performance.

6.1 Thematic Clusters 1- (Problem-Focused Directions) - Advancing Multidimensional Models of Cost, Time, and Risk Escalation

It is true that many studies have been conducted to determine the causes of project delays, overruns, and material price volatility [4],[45],[48], but the way forward should be taken in the next generation of research, where integrated models, using comprehensive datasets, would be used to determine the complex interactions between material inflation, macroeconomic shocks, supply-chain disruptions, and project-level uncertainties. As the material cost can reach up to 60% of the project costs, more detailed studies on the behavior of steel, concrete, and other material are needed to understand the escalation behavior [2],[7]. Moreover, the emergence of new forecasting methods based on ARIMA and neural networks as well as hybrid econometric models [9],[10],[12],[5],[17] indicates that comparative assessments of prediction models are necessary, which would allow comparing the predictive accuracy in periods of sharp market fluctuations. Inter-country comparisons, especially across the developing economies, might also help to determine how contextual factors influence the pattern of escalation, contractor performance, and risk exposure of the project. To enhance theoretical knowledge, more studies are needed in the future to incorporate system dynamics, agent-based modeling, and probabilistic models to expose the pathways of escalation throughout the whole lifecycle of projects.

6.2 Thematic Clusters 2 - (Solution-Focused Directions) - Developing Strategic, Knowledge-Based, and Technology-Enabled Escalation Management Frameworks

The availability of keywords of solution orientation, which includes the words “knowledge,” “strategy,” “tool,” “implementation,” and “practice,” shows that there is a positive trend toward managerial, contractual, and digital innovations in managing cost escalation. To create holistic decision-support ecosystems in which market intelligence is combined with project planning, future researchers should expand on knowledge-based risk tools [50], multi-criteria evaluation frameworks [46], and system-dynamics approaches [47]. The quick improvement of AI-based forecasting (Deep AR, neural networks, game-theoretic models, and others) [11],[20],[21] suggests the necessity of usable digital platforms that can be used to convert the predictive output to the real-time strategic response of the contractor and client. Further studies are needed to determine the effectiveness of these tools in real-world settings and especially at turbulent economic times. Additionally, current discussions regarding contract adequacy and the idea of escalation clauses [13],[14] indicate that the studies analyzing adaptive contracting strategies and incentive systems as well as the policy changes that raise the resiliency to unexpected material changes in price should be conducted. Simultaneous efforts in the area of knowledge-sharing practices, supply chain coordination, and organizational learning would also contribute to the capacity building of proactive escalation management.

7. Research Contributions and Limitations

This study makes three original contributions:

- i. it reveals a temporal paradigm shift in material cost escalation research using burst detection.
- ii. it integrates problem-diagnostic and solution-oriented themes into a unified evolutionary framework, and
- iii. it identifies post-2022 digital mitigation strategies as a dominant emerging research trajectory.

This study has certain limitations. One limitation of the analysis is that only studies indexed in the Dimensions database are included, and this could exclude relevant studies that are only indexed in other databases like Scopus or Web of Science. Second, the results depend on the use of search terms and may not reflect every variation of material cost escalation. Third, bibliometric analysis is interested in publication patterns but does not validate findings through real-world project data. Future studies should apply multi-database analysis and empirical studies using project-level data to support the identified trends and enhance the practicality of the cost escalation models.

8. Conclusion

This paper presents a systematic and data-driven mapping of global studies on the rising costs of construction materials between 2002 and 2025 by integrating bibliometric performance analysis, keyword co-occurrence mapping, and temporal bursting studies.

From the publication trend analysis, it was observed that the interest in research on the topic of construction material price volatility and project cost instability has increased significantly after 2012, as there is an increasing concern worldwide on this topic. The bibliometric results showed that Nigeria, China, Malaysia, and India are major countries contributing to the number of publications, while the top institutions producing publications are the Hanyang University, Obafemi Awolowo University, and Tun Hussein Onn University of Malaysia. The analysis also indicated that the intellectual development of the field was dominated by high-impact journals like International Journal of Project Management, Journal of Construction Engineering and Management, Automation in Construction, and Journal of Cleaner Production. Unlike past reviews, which focused foremost on cataloguing factors that contribute to delay and cost overruns, this research goes further in advancing the understanding of the topic by identifying structural thematic inflection points and quantifying the intensity of research acceleration over time. The results show that the early stage of scholarship was mainly of the diagnostic type, focusing on complexity of project, construction of projects, and cost-related problems. Temporal analysis of bursts shows a large structural shift in about 2012, representing a change towards more intensive project-level investigations. Themes such as complex building, building projects, construction projects, etc. saw an early and evident strong acceleration, i.e., an increasing empirical focus on the performance of projects in volatile material conditions. The issue of cost overrun(s) was a recurring and significant concern in 2023 – it was clearly a center of discussion in the developing discussion about material price volatility and project viability.

More recent bursts, beginning in 2023-2024, indicate the growing importance of stakeholders' collaboration, of the application of BIM-related methods and of construction readiness, and thus an emerging trend towards governance-oriented approaches and digital support for mitigation strategies. The findings suggest an evolutionary path that leads from problem diagnosis to integrated and capability-based responses, aimed at enhancing resilience against material price fluctuations, rather than a universal paradigm shift. The declining-theme analysis also showed that there is a decreasing emphasis on the traditional project-oriented and generic management themes, suggesting a general trend of adopting digital, collaborative, and resilience-oriented research approaches in studies of material cost escalation. By fusing structural network mapping with the detection of temporal bursts, this study moves beyond descriptive aggregation to provide an understandable perspective on when and how research priorities have changed. The results add theoretically by clarifying the developmental pathway of material cost escalation research and practically by emphasizing the importance of coordinated stakeholder strategies, digital integration, and preparedness frameworks to manage future market uncertainty. Overall, the study lays the groundwork in a structured way for future studies that attempt to incorporate

material-specific price dynamics with project performance analytics and adaptive management strategies into more resilient building systems.

9. Statements & Declarations

Author Contributions

All authors actively participated in the development and execution of this study. Material preparation, data collection, and data analysis were mainly the duties of SSD. The manuscript was originally written by SSD and then JAP did the proofreading and review. Final manuscript was approved by all authors.

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Consent for publication

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Data Availability Statement

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