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Safety Criteria in Buildability: Insights from a Bibliometric Analysis in Disaster Contexts

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Abstract
In the context of disasters, buildability is not limited to efficiency during the construction process; it also encompasses structural integrity, occupational health and safety conditions, and the capacity to adapt to environmental challenges. This study examines 297 academic publications published between 2000 and 2025 through bibliometric methods to analyze the relationships among buildability, safety, and disaster resilience. The findings reveal a significant increase in publication numbers after 2017, with the highest volume recorded in 2024. Country-level distribution indicates that China, the United States, and the United Kingdom are the most productive contributors, while international collaborations are concentrated primarily around European and Asian networks. Citation analyses demonstrate that a limited number of pioneering studies have achieved high visibility, whereas the overall distribution of citations remains fragmented. Author collaboration networks show that interdisciplinary partnerships have increasingly strengthened, particularly at the intersection of architecture, civil engineering, and disaster management. Keyword co-occurrence analyses highlight themes such as "sustainable development", "risk management", "modular construction", and "disaster resilience", while also pointing to the scarcity of systematic review studies. In conclusion, this study systematically uncovers the conceptual gap between buildability and disaster resilience and aims to contribute to the development of a more holistic framework for future research.

Keywords
bibliometric analysis, buildability/constructability, safety, disaster, resilience

1. Introduction

The rapid pace of urbanization, climate change, and the increasing frequency of natural disasters necessitate buildings that are not only durable but also realized in a fast, safe, and sustainable manner [1]. Earthquakes, floods, and wildfires have revealed the vulnerabilities of existing building stocks during post-disaster shelter and reconstruction [2]. In this context, buildability – defined as the efficient, rapid, and safe realization of construction – has gained critical importance alongside safety-oriented design. Buildability is a multidisciplinary concept encompassing safety, speed, cost, labor organization, and quality from design to construction [3, 4]. It also includes occupational health and safety, structural integrity, material selection, and environmental adaptation [5, 6]. Safety criteria protect workers and ensure completed buildings withstand fire, earthquakes, and other disasters, making safety-oriented buildability essential in disaster management [7].

The literature emphasizes that buildability and disaster safety are interrelated. Effective approaches can reduce casualties, minimize damage, and enhance rapid response [8]. Recent studies have integrated circular economy principles, sustainable materials, and modular techniques. For instance, smart shelter prototypes developed by Karimi et al. [1] promote sustainability through reusable materials. Similarly, Hernández [9] and Han et al. [10] stress off-site modular production for rapid and safe assembly, while Aggabou et al. [11] highlight AI-based risk models for early hazard detection. Early risk analysis, stakeholder communication, modularity, and circular economy principles further strengthen resilience [12, 13].

These studies show that safety and buildability in disaster contexts form an emerging interdisciplinary field. Yet, systematic syntheses at their intersection remain limited. This study therefore seeks to identify trends, thematic clusters, and research gaps by addressing the following questions:

- What are the development trends of buildability literature in the context of disasters?
- Which countries, institutions, and authors have contributed most?
- Through which thematic clusters are safety criteria addressed?
- What gaps exist and what future opportunities can be identified?

2. Methodology

This study employs bibliometric analysis to examine the literature on buildability and disaster safety. Bibliometric analysis is a quantitative method that reveals publication trends, citation relationships, collaboration networks, and thematic developments within a given research field by means of objective data [14, 15]. In this respect, the study aims not only to present numerical indicators of the literature but also to systematically evaluate its conceptual gaps, dominant themes, and emerging research opportunities.

2.1. Data Source and Keyword Selection

The dataset was collected from the Scopus and Web of Science (WoS) databases. Keywords included "buildability", "constructability", "disaster resilience", "risk", and "construction safety", applied in various combinations to capture terminological variations and intersections with disaster safety. Table 1 presents a sample search query from Scopus and WoS, filtered by titles, abstracts, and author keywords.

Table 1. Summary of the systematic search of the Scopus-WoS database used in the study

Database	Date of search	Searching criteria in title, abstract and keywords	Number of Documents
• Scopus • Web of Science (WoS)	08.08.2025	(TITLE-ABS-KEY ("buildability" OR "constructability") AND TITLE-ABS-KEY ("safety" OR "safe" OR "risk" OR "safely" OR "hazard") AND TITLE-ABS-KEY ("disaster" OR "post-disaster" OR "emergency" OR "shelter" OR "crisis" OR "disaster housing" OR "resilience" OR "rapid assembly" OR "easy-to-assemble")	297

2.2. Analytical Tools

During the analysis, two software tools were employed. **VOSviewer** [16] was used for co-authorship, co-citation, and keyword co-occurrence analyses, enabling visualization of relationships among publications, authors, institutions, and keywords. **Bibliometrix R-Package** [14] was applied for thematic mapping, publication trends, citation analyses, and statistical evaluations through its Biblioshiny interface. The combined use of these tools strengthened methodological rigor and interpretive depth, ensuring a robust and multidimensional mapping of literature.

2.3. Characteristics of the Dataset

To ensure methodological transparency, the publication selection followed the PRISMA framework, clarifying the stages of identification, screening, and inclusion, and thereby enhancing replicability (Figure 1). Initially, 304 records were retrieved; after removing duplicates and irrelevant studies, 297 documents remained for analysis. Filtering, based on titles, abstracts, and author keywords, covered subject areas such as engineering, materials science, environmental science, economics, disaster management, and other multidisciplinary fields. Only English-language publications indexed in Scopus and Web of Science (WoS)—including journal articles, conference proceedings, and reviews—were considered. The final dataset, spanning 2000–2025, comprised 297 documents from 125 sources authored by 987 scholars; no relevant publications were identified before 2000.

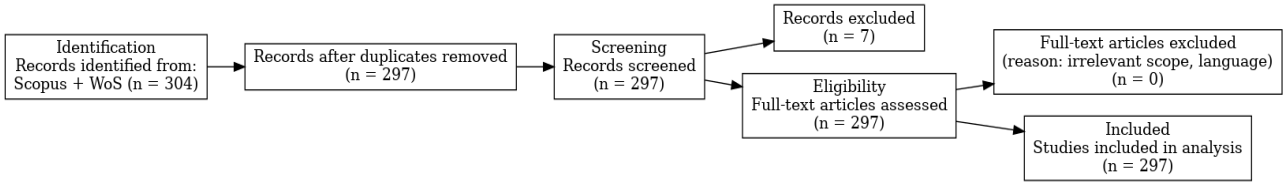

Fig. 1. PRISMA flow diagram of the study selection process

3. Findings and Discussion

This bibliometric analysis identified publication trends, collaboration networks, and thematic developments in studies on buildability/constructability, sustainability, and disaster safety published between 2000 and 2025. The results emphasize both the historical growth of the field and the conceptual clusters and interdisciplinary interactions that have shaped its evolution.

3.1. Publication Trends

Within this scope, the analysis examines the annual distribution of publications, publication types, and trends across countries and institutions.

- **Publication Count**

An examination of publication counts by year reveals that scholarly output was highly limited in the early 2000s. However, a notable increase has occurred since 2017, with the number of publications reaching 16 in 2020, 21 in 2021, 42 in 2022, and peaking at 79 in 2024. Although the data for 2025 remain incomplete, the fact that 45 studies have already been recorded indicates that the upward trend is continuing (Figure 2). This trajectory reflects the growing academic interest in buildability and safety-oriented research.

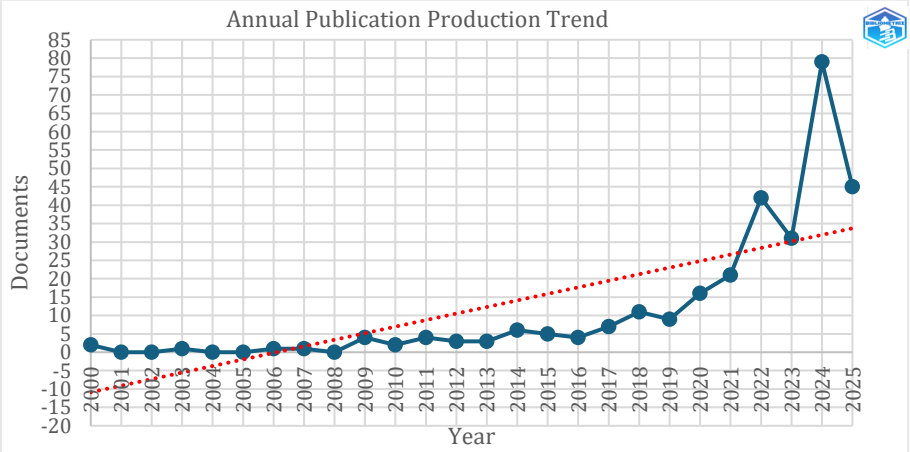

Fig. 2. Distribution of the number of publications per year related to studies in literature

- **Publication Type**

An analysis of the distribution of publication types indicates that peer-reviewed journal articles constitute the largest share, while conference papers account for a smaller portion, and review studies remain relatively limited (Figure 3). The predominance of journal articles demonstrates that the topic has been extensively addressed in academic outlets, whereas conference proceedings tend to reflect more applied and contemporary discussions. The relative scarcity of review publications highlights the lack of comprehensive systematic reviews within this field.

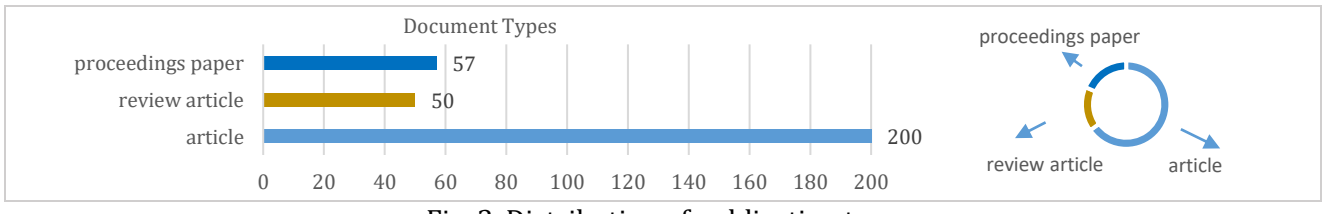

Fig. 3. Distribution of publication type

- **Distribution of Research Topics**

Most of the analyzed publications are concentrated in the field of engineering (89.4%), followed by materials science (12.5%) and environmental sciences (5.9%). Contributions from economics, econometrics, and finance remain minimal (1.3%). This distribution indicates that the topic of

buildability and disaster safety is predominantly addressed within the framework of technical disciplines (Figure 4).

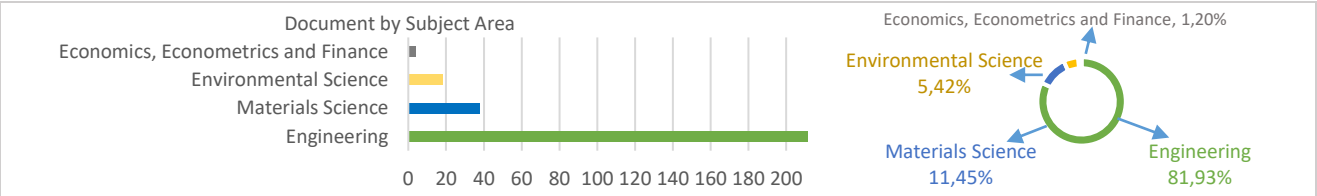

Fig. 4. Distribution of subject areas related to studies conducted in literature

- **Diversity of Publication Sources**

The study examined the top 20 sources with the highest number of publications (Figure 5). Among the leading journals are Automation in Construction (35), Buildings (31), Journal of Building Engineering (31), Asian Journal of Civil Engineering (22), and Construction and Building Materials (7). In terms of conference proceedings, the ASEE Annual Conference and Exposition (3 publications) and the Canadian Society for Civil Engineering Annual Conference Proceedings (3 publications) are particularly notable. This diversity demonstrates that the research field is strongly represented in both theoretical and applied dimensions.

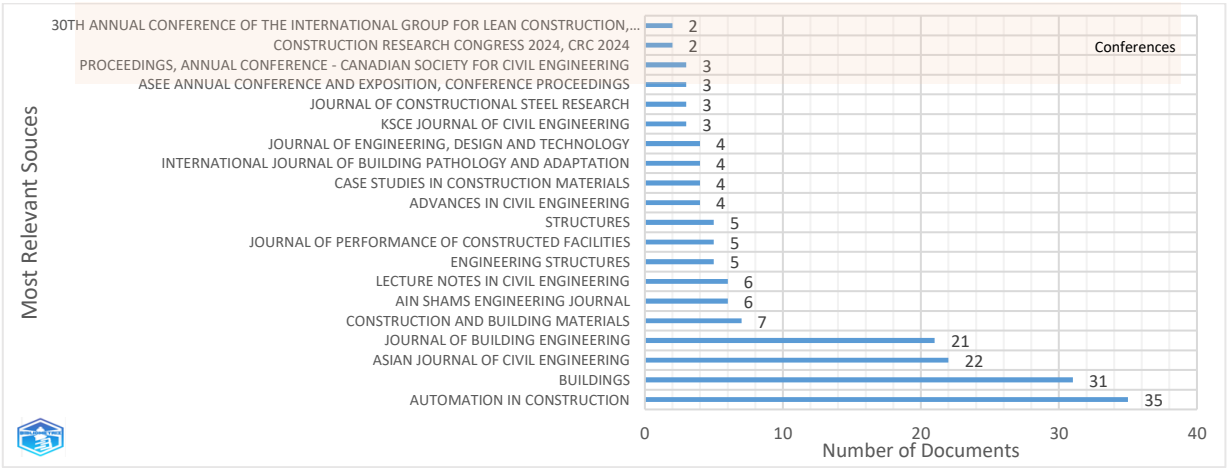

Fig. 5. Sources in which the studies were published

- **Country Distribution**

In the distribution of publications by country, the United States (58) and China (51) occupy the leading positions, playing a decisive role in shaping the research agenda. India (21), the United Kingdom (17), and Australia (16) follow as other prominent contributors. Despite its high disaster risk, Türkiye ranks in the middle with relatively limited output (Figure 6). This finding indicates that the research capacity in high-risk regions has not been sufficiently reflected in scientific outputs.

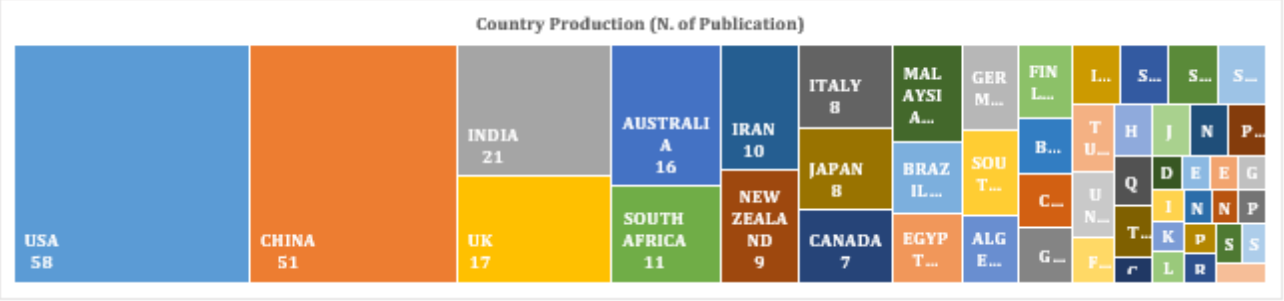

Fig. 6. Distribution of publication counts by country

3.2. Keyword and Conceptual Distribution Analyses

The keyword cloud and conceptual distribution highlight the main research areas in the literature. Figure 7 shows the 20 most frequent keywords, with *construction industry* (52), *architectural design* (38), *building information modelling (BIM)* (29), and *project management* (26) as the most prominent, indicating strong links between buildability, disaster themes, and construction practice. The terms *sustainable development* (25) and *sustainability* (19) further demonstrate that buildability extends beyond technical aspects to environmental and sustainability perspectives. Keywords such as *decision making* (16), *risk assessment* (11), and *seismic design* (12) emphasize the importance of risk management and decision processes in disaster-resilient construction. Finally, the growing presence of next-generation technologies—such as 3D printing and virtual reality—suggests that digitalization and innovation are increasingly seen as strategies for mitigating disaster risks.

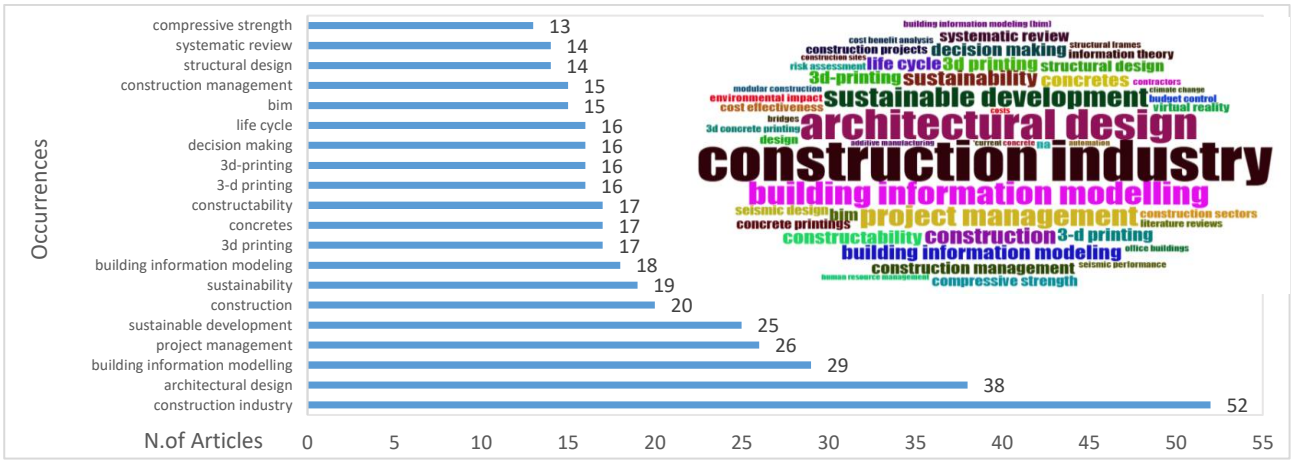

Fig. 7. The keyword cloud and occurrences

- **Network Analysis and Conceptual Clusters**

The bibliometric network analysis reveals the fundamental conceptual clusters within the literature. The co-occurrence analysis conducted in this study identified six major clusters (Figure 8). At the center of the network lies construction industry, while architectural design, building information modelling (BIM), project management, and sustainable development represent the key associated clusters.

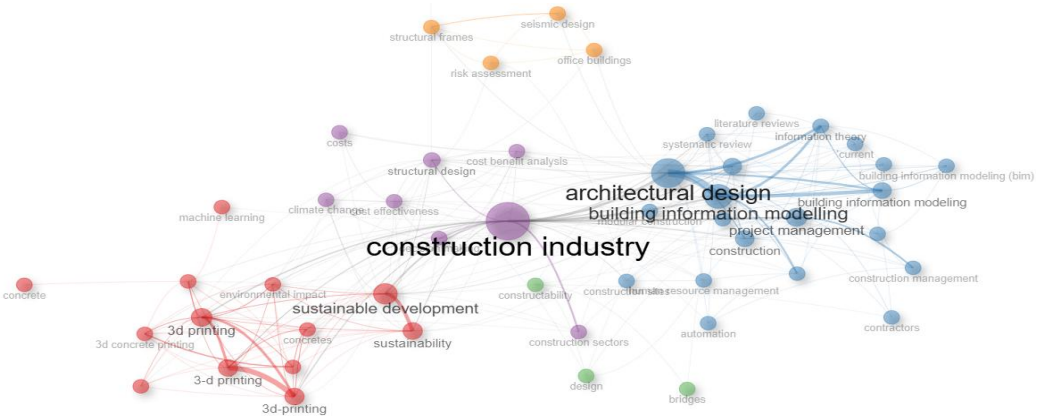

Fig. 8. Co-occurrence Network

In addition, the measures of Betweenness and PageRank were employed to assess the structural role of keywords within the network. Betweenness highlights bridging terms that connect different clusters, thereby identifying interdisciplinary transition points. Accordingly, construction industry (439,599), architectural design (238,729), and structural design (72,803) emerged as the most influential bridging concepts (Figure 9). PageRank, on the other hand, measures the centrality of terms within the network,

identifying the concepts most frequently connected with others. The results show that construction industry (0.089) and architectural design (0.068) hold central positions, confirming that the theoretical and practical foundations of the field remain largely shaped around the construction sector and design processes (Figure 9) [17, 18].

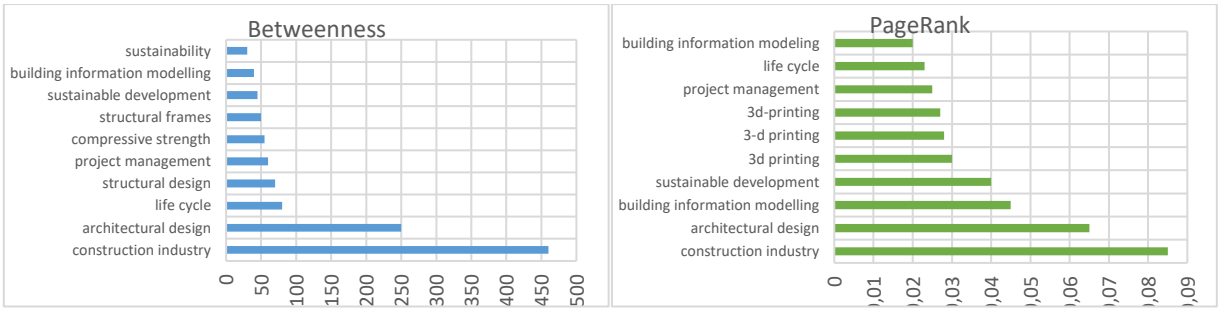

Figure 9. The top 10 concepts with the highest betweenness centrality and PageRank values

- **Thematic Trends**

Overall, the network analyses demonstrate that academic studies in the construction sector are structured around three primary thematic foci:

1. Digitalization: Building Information Modelling (BIM), automation, and information modelling.
2. Sustainability: 3D printing, environmental impact, and sustainable development.
3. Risk and Resilience: Seismic design, risk management, and safety practices.

While digitalization and sustainability constitute parallel and mutually reinforcing research streams, the theme of risk and resilience represents a comparatively narrower strand yet underscores the safety dimension of the construction industry.

3.3. Citation Analysis and Most Influential Studies

This section presents citation analyses and highlights the seminal studies that most strongly link buildability with disaster resilience.

- **Distribution of Publications and Citations by Year**

Average citation rates fluctuated: high in the early 2000s, declining between 2003–2008, briefly rising in 2011, and steadily increasing after 2018. The peak in 2020–2021 reflected growing international interest in buildability and disaster safety, but values have declined again since 2022 (Figure 10). Comparisons show that early studies gained far greater visibility, with an average of 123 citations per article in 2000 versus only 6.05 in 2024. This indicates that pioneering works had significant impact, while the rapid growth of recent publications has dispersed citations and limited the visibility of newer studies.

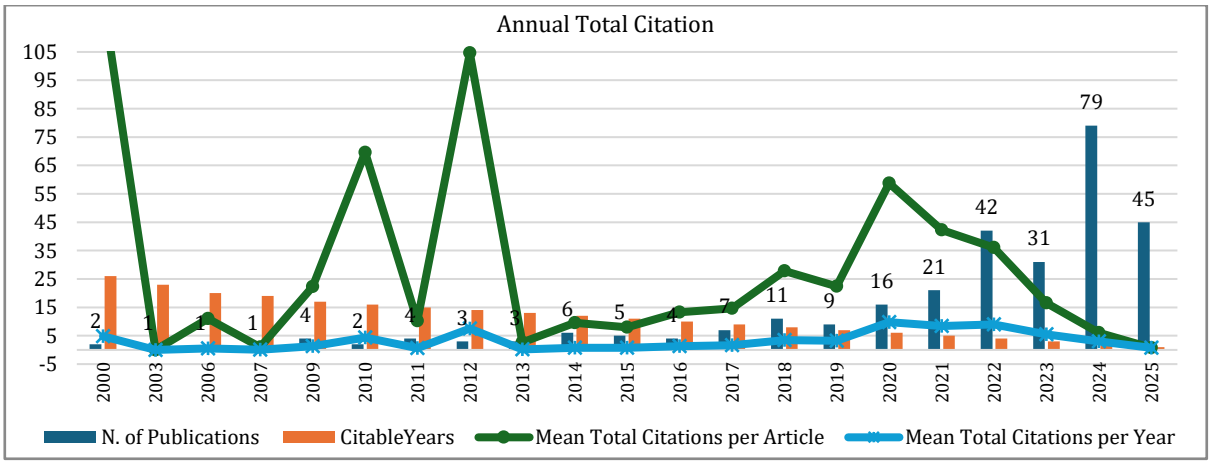

Figure 10. Annual distribution of total publications, citable years, and mean citation indicators

Cross-country citation performance reveals significant differences. The United States (1177) and China (1011) lead in total citations but have lower averages per article, while the United Kingdom (594) and Australia (575) show stronger visibility with fewer publications. Italy and Spain stand out for high average citation rates despite limited outputs, whereas India's large volume but only 25 citations reflect low impact. Iran (130) and South Africa (136) also achieved notable performance with modest outputs (Figure 11). These findings indicate that even limited studies from high-disaster-risk regions can have considerable influence. However, countries such as Turkey have yet to realize this potential, highlighting the need to strengthen scholarly output to transfer local disaster experiences into global knowledge and advance buildability in resilience-oriented construction research.

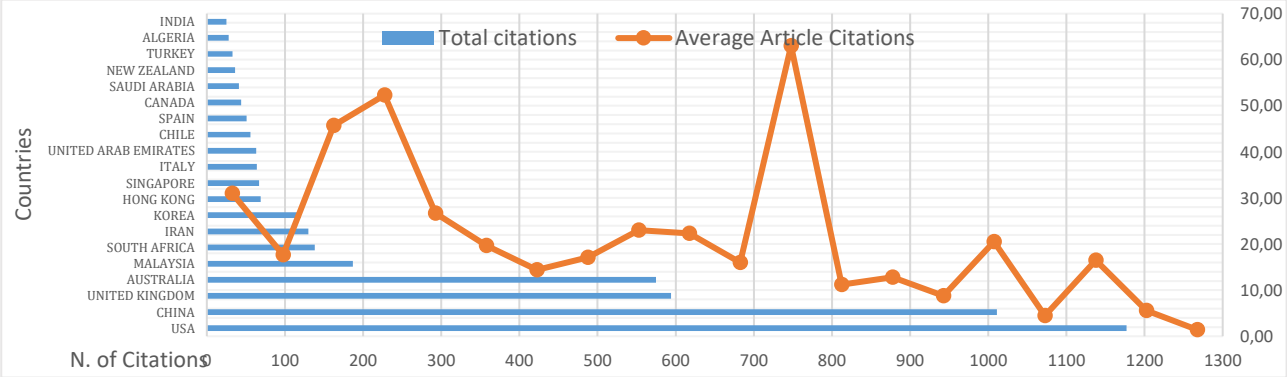

Figure 11. "Citation Distribution by Country: Total and Average per Article

3.4. Section Evaluation

Publication trends show a sharp rise after 2017, driven by international disaster risk reduction policies and the integration of technologies such as BIM, modular construction, and AI. Geographically, the United States and China dominate in volume, while the United Kingdom and Australia achieve greater visibility with fewer studies, reflecting stronger qualitative impact. Turkey, despite its high disaster risk, contributes little. Conceptual analyses highlight three dominant themes: digitalization (BIM, automation), sustainability (3D printing, environmental impacts), and risk–resilience (seismic design, safety management), confirming the field's multidisciplinary scope. Citation patterns further reveal that early studies remain seminal and highly visible, while the growing volume of recent work has yet to achieve comparable influence, indicating the field's trajectory continues to be shaped by foundational research.

4. Conclusion

This study systematically mapped the conceptual intersection between buildability and disaster safety, identifying thematic clusters, trends, and research gaps. Findings show that buildability in disaster contexts extends beyond construction efficiency to include structural integrity, occupational safety, and adaptability to environmental challenges. Effective practices enhance emergency response, shorten construction times, and strengthen the resilience of both temporary and permanent shelters. Since 2018, publications on the buildability–safety–resilience nexus have markedly increased, with "sustainable development," "rapid construction," and "safety management" emerging as key themes, although aspects such as risk reduction, rapid assembly, and user safety remain underexplored.

The results further indicate that modular construction and industrialized production improve occupational safety and provide effective solutions for rapid post-disaster reconstruction. AI-based risk management supports resilience by anticipating hazards, while early risk assessment, durable materials, and multi-stakeholder communication are critical for resilient design. Strategies such as modularity, evacuation planning, maintenance ease, and circular economy principles also enhance adaptability in shelter prototypes. Yet these dimensions are often addressed in isolation, with limited integration of digital technologies, particularly BIM and off-site construction—and insufficient attention to decision-making and policy frameworks.

In conclusion, this bibliometric study highlights key trends, gaps, and priorities at the intersection of buildability and disaster safety. Digital transformation, AI-based risk management, and circular economy strategies show significant potential to improve reconstruction effectiveness and resilience. Future research should integrate systematic reviews, multi-stakeholder decision-making, policy frameworks, and digital tools (e.g., BIM, off-site construction), while incorporating empirical evidence from high-risk regions to advance both theoretical and practical contributions.

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