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BEYOND EFFICIENCY: RETHINKING OFF-SITE CONSTRUCTION FOR POST-DISASTER HOUSING RECONSTRUCTION

A.P. Rathnasinghe[1], R.V.A.D. Rahubadda[2], N. Thurairajah[3] and Udayangani Kulatunga[4]

ABSTRACT

The rising frequency and severity of natural hazard-induced disasters has heightened the need for reconstruction strategies that are rapid, yet resilient and responsive to long-term community needs. Off-site construction (OSC) has emerged as an effective approach to post-disaster reconstruction (PDR), offering accelerated delivery, enhanced quality control, and reduced on-site disruption. However, existing research is found to distort OSC's potential by primarily emphasising technical efficiencies while overlooking major barriers such as standardisation issues, cultural insensitivity, and inadequate policy integration. This paper addresses this distortion by conducting a systematic scoping review, supplemented by scientometric analysis. The scientometric review analyses 113 peer-reviewed publications across the years 2004–2025, retrieved from the Scopus database, identifying dominant research themes including modular construction, sustainability, and resilience. Concurrently, the systematic review highlights OSC's key advantages—most notably, time and cost efficiencies—as well as persistent challenges such as high initial investment, logistical constraints, limited policy integration, and insufficient community involvement. Critically, the review suggests that OSC's effectiveness cannot be measured solely by technical efficiency, as the delivery of standardised, culturally disconnected housing may undermine broader recovery goals. For OSC to contribute meaningfully to sustainable reconstruction, it must be integrated within a holistic framework that values local context, supports community agency, and fosters a transition from shelter to home. This study underscores the need for more adaptive, inclusive, and policy-aligned models of OSC in post-disaster settings.

Keywords: *Disaster Resilience; Housing; Off-Site Construction (OSC); Post-Disaster Reconstruction (PDR); Systematic Review.*

1. INTRODUCTION

The global incidence of natural hazard-induced disasters has increased markedly in recent decades, both in frequency and severity (Guha-Sapir et al., 2013). This escalation is

[1] Lecturer, Faculty of Engineering and Environment, Northumbria University, Newcastle-upon-Tyne, NE1 8ST, United Kingdom, akila.rathnasinghe1@northumbria.ac.uk
[2] Research Assistant, Department of Building Economics, University of Moratuwa, Sri Lanka, dilrukshaashen@gmail.com
[3] Associate Professor, Faculty of Engineering and Environment, Northumbria University, Newcastle-upon-Tyne, NE1 8ST, United Kingdom, niraj.thurairajah@northumbria.ac.uk
[4] Professor, Department of Building Economics, University of Moratuwa, Sri Lanka, ukulatunga@uom.lk

compounded by the persistent rise in global temperatures and sea levels, which continues to pose profound and increasingly unmanageable challenges for many nations (Huang et al., 2018). Even if the most ambitious climate mitigation pledges are fully implemented, they are still projected to be insufficient to stop further global temperature rise (IPCC, 2023). Consequently, extreme weather events are expected to become more frequent and more destructive. These climatic threats are further intensified by rapid population growth and expanding infrastructure, which together have elevated global exposure and vulnerability to natural hazards (Bournay, 2007). As reported by the International Displacement Monitoring Centre, approximately 14 million individuals are displaced annually due to natural disasters (Rashidi & Ghalambordezfooly, 2025).

In response to this growing crisis, governments, policymakers, and humanitarian organisations are increasingly prioritising disaster resilience and preparedness as core policy concerns (Thurairajah et al., 2019). Recognising that no nation is immune to disaster risks, strategic improvements in disaster management—grounded in coordination, foresight, and logistical capability—have become imperative (Guha-Sapir et al., 2013). Within this broader landscape, post-disaster reconstruction (PDR) of houses emerges as one of the most complex yet critical dimensions of recovery (Siriwardhana et al., 2021). Unlike conventional housing projects, PDR of houses must contend with severe time constraints, limited resources, logistical bottlenecks, and the often-fragile socio-environmental contexts of affected areas (Rathnasinghe et al., 2021).

PDR is frequently hindered by chronic delays (Tas et al., 2010), with slow reconstruction prolonging displacement, heightening human suffering, and escalating costs (Weerakoon et al., 2007). On the other hand, financial limitations are acute (Lloyd-Jones, 2006), exacerbated by weak insurance mechanisms and disproportionate emphasis on short-term relief (Ginigaddara et al., 2023). Disrupted supply chains, resource shortages, and labour constraints, further impede progress and compromise construction quality (Rapone et al., 2024). Moreover, fragmented governance, inadequate inter-agency coordination, and top-down planning continue to undermine the effectiveness of reconstruction efforts (Rashidi & Ghalambordezfooly, 2025). At the same time, the pursuit of sustainable and resilient reconstruction—though increasingly recognised as essential—remains constrained by logistical, institutional, and contextual barriers (Rathnasinghe et al., 2024). Conventional construction typically operates within predictable and controlled environments with established timelines, budgets, and logistics, whereas PDR must navigate significant uncertainty, accelerated timelines, resource scarcity, and compromised infrastructure. These unique constraints amplify the relevance and potential of alternative construction techniques in addressing the pressing demands characteristic of disaster recovery contexts (Rathnasinghe et al., 2024).

Amid these challenges, interest in alternative construction strategies has grown, with particular attention to the potential of off-site solutions. Recent efforts have focused on proactive measures such as the deployment of prefabrication and decentralised logistics hubs to support emergency response and reconstruction (Shahzad et al., 2022). Off-site construction (OSC), defined as the manufacturing of prefabricated and non-prefabricated components in controlled factory environments (Rashidi & Ghalambordezfooly, 2025), has gained recognition for its capacity to enhance speed, quality, and efficiency in the built environment. Notably, modular approaches have demonstrated advantages including reduced material waste (MBI, 2010), enhanced quality assurance (Liu et al., 2021), reduced environmental impact (Rathnasinghe et al., 2024), and improved health and safety (MBI, 2010). Other frequently cited benefits include time and cost savings, decreased dependency on manual labour, and decreased resource depletion (Won et al., 2013). As a premise, OSC represents a promising means for addressing both the speed and quality imperatives of PDR, with potential contributions to more adaptive and resilient recovery systems (Goulding & Rahimian, 2019).

Yet, while OSC has demonstrated clear technical and logistical benefits, its effectiveness in post-disaster contexts cannot be deduced to construction efficiency alone. Research suggests that the provision of standardised, prefabricated dwellings—absent community input, cultural sensitivity, or long-term integration—can undermine the social objectives of reconstruction (Rathnasinghe et al., 2021). Accordingly, a critical appraisal of OSC's potential, limitations, and future pathways when deployed in the PDR of houses is needed. Thus, this study addresses the following research question:

How has Off-Site Construction (OSC) evolved and contributed to post-disaster reconstruction (PDR) of houses, and what are the knowledge gaps, challenges, and future opportunities in its application?

To answer this, the study presents a scientometric and systematic scoping review of 113 peer-reviewed publications from 2004–2025. By synthesising thematic trends, identifying gaps, and evaluating practical implications, this study aims to reposition OSC not as a mere technical fix for PDR of houses, but as a component of a more holistic, inclusive, and policy-aligned reconstruction paradigm.

2. METHODOLOGY

The study adopted a two-phase review methodology integrating scientometric and systematic review techniques. The process involved identifying, screening, and analysing relevant literature, guided by a transparent and replicable methodology.

2.1 LOCATING BIBLIOMETRIC DATA

Scopus was selected as the primary database due to its broader source coverage compared to alternatives such as Web of Science (Rathnasinghe et al., 2024). The search strategy was designed around three interrelated thematic areas: *Off-Site Construction, the Construction Industry, and Post-Disaster Reconstruction*. Specifically, the search utilised comprehensive Boolean logic, systematically combining keywords as follows: ("off-site construction" OR "modular construction" OR "industrialised building systems" OR "prefabricated construction" OR "prefabricated housing" OR "modular building" OR "factory-built housing") AND ("post-disaster" OR "disaster recovery" OR "emergency housing" OR "temporary housing" OR "reconstruction"). The keyword combinations were consistently applied across all database searches to ensure replicability and transparency.

2.2 SELECTION OF THE MOST RELEVANT BIBLIOMETRIC DATA

To ensure methodological rigour, a defined set of inclusion and exclusion criteria was applied during the screening process. These criteria are presented in Table 1.

Table 1: Inclusion and exclusion criteria of research publications

Inclusion Criteria	Exclusion Criteria	Rationale
Publications in English language	Non-English publications	English was adopted for consistency and accessibility in global academic discourse
Publication years 2004–2025	Publications before 2004	The 2004 Indian Ocean tsunami was a turning point in global PDR discourse
OSC and PDR addressed jointly or partially in scope	Studies focusing solely on OSC without disaster context	The study is scoped specifically around OSC's role within post-disaster reconstruction
Peer-reviewed journals or indexed conference proceedings	Non-indexed publications	Ensures academic quality, reliability, and traceability

In determining eligibility, conceptual and theoretical papers were included only if they explicitly provided empirical evidence, rigorous analytical insights, or detailed case-study discussions related to OSC in post-disaster contexts. Purely theoretical or opinion-based articles lacking empirical substantiation or specific practical implications were excluded to maintain analytical rigour. Following this, the selection process adhered to Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Moher et al., 2009), as depicted in Figure 1. Using the initial keyword search, a total of 152 studies were retrieved from Scopus databases.

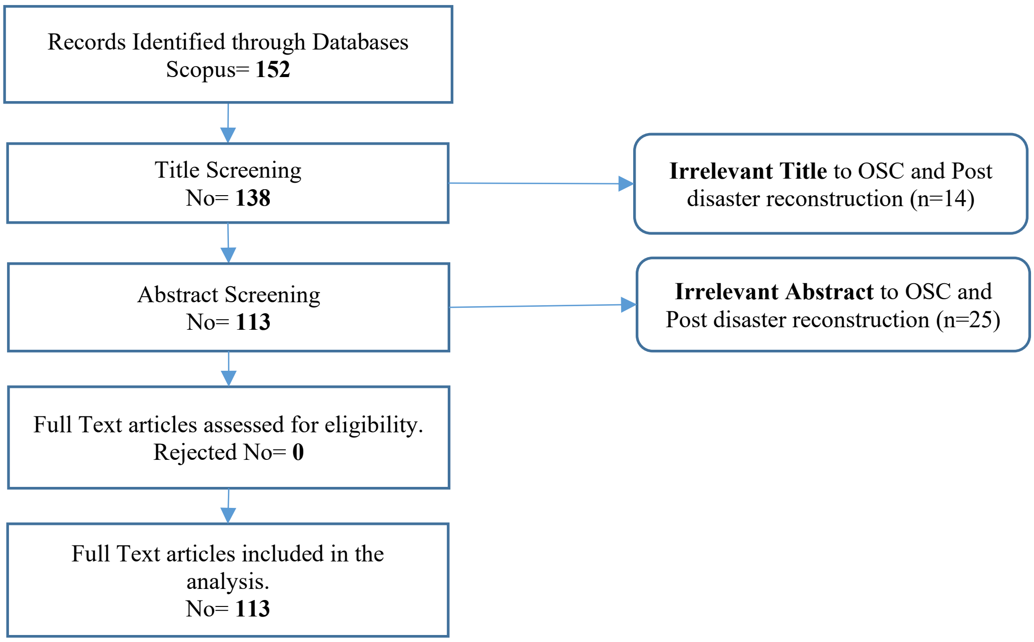

Figure 1: PRISMA guideline for evaluation and screening of retrieved articles from database search

After examining for duplicates and screening abstracts, 39 studies were excluded. The remaining 113 studies met all inclusion criteria and were retained for full-text review and analysis.

2.2.1 Scientometric Review

Rathnasinghe et al. (2024) emphasised scientometric review as an effective mapping tool for visualising connections between keywords, as well as collaborations among researchers, institutions, and countries. In this study, the VOS viewer software was used to generate co-occurrence networks of keywords from the selected 113 publications, allowing the identification of thematic clusters and emerging trends. Overlay visualisation further facilitated the temporal analysis of keyword prominence, revealing how the academic discourse has evolved over the period.

2.2.2 Systematic Review

As part of the review methodology, a systematic review was conducted to delve into the content of the 113 selected publications and assess the depth of knowledge on OSC in PDR. Although scientometric review method effectively maps research networks, it offers limited depth in content interpretation. Therefore, each included article was read in full and critically analysed to extract pertinent information focusing on three core aspects reported in the literature: (1) the advantages/benefits of utilising OSC for post-disaster reconstruction, (2) the challenges or barriers encountered in implementing OSC in such contexts, and (3) the outstanding knowledge gaps or research needs identified.

While the methodological design ensured both breadth and depth, several limitations must be acknowledged. First, the exclusivity of Scopus as the source database may have introduced a degree of publication bias, excluding relevant studies indexed elsewhere or published in non-English languages. Second, the scientometric analysis was purposely scoped to focus on keyword co-occurrence and thematic mapping, excluding dimensions such as author collaboration networks or geographic spread. Finally, although the systematic review aimed to extract and synthesise themes rigorously, it inevitably involved interpretive judgement. Nonetheless, these limitations were mitigated by transparent selection criteria and a reflexive review process, thereby ensuring a robust and credible foundation for the findings presented.

3. FINDINGS OF THE SCIENTOMETRIC REVIEW

This section discusses the scientometric review findings facilitated by VOS Viewer. The trajectory of publications over the studied period and keyword-occurrence are discussed.

3.1 THE ANNUAL PUBLICATION TREND

Figure 2 presents the annual output of research on OSC in PDR, revealing a clear upward trajectory over the past two decades.

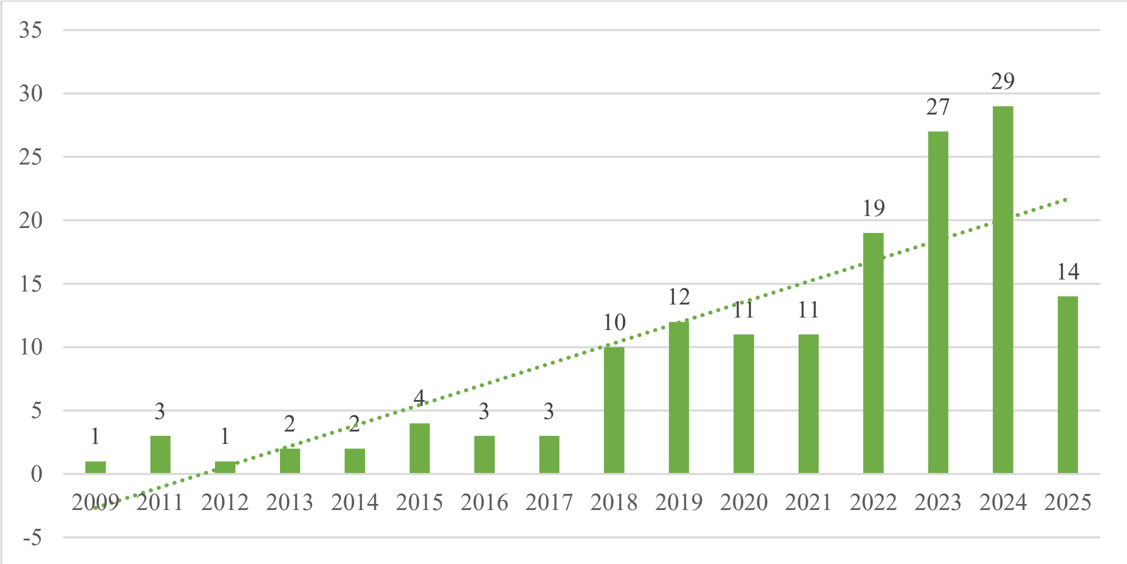

Figure 2: Annual research publications on off-site construction in the context of post disaster reconstruction

From the mid-2000s through the mid-2010s, publication counts remained modest (on the order of 1–4 per year), indicating that OSC in PDR was a niche focus during that period. A pronounced inflection occurs around 2018, after which the volume of publications accelerates markedly – rising to about 10 papers in 2018 and continuing to climb to a peak of 29 in 2024. This steady growth in output suggests that OSC in PDR of houses has moved into the mainstream of scholarly attention. The surge after 2018 likely reflects a confluence of factors: the escalating frequency of climate-induced disasters heightening the urgency for faster reconstruction methods, and technological advances (e.g. modular design, digital fabrication) that made off-site approaches more feasible and appealing. While a slight drop in 2025 (14 publications as of data collection) is observed, this is likely due to incomplete data for that year or a natural stabilisation after the 2024 peak. Overall, the publication trend underscores an increasingly vigorous research focus on OSC within disaster resilience discourse, marking the transition of this topic from a fringe interest to a prominent scholarly domain.

3.2 Co-occurrence Network of Keywords

The VOSviewer's keywords co-occurrence mapping (Figures 3–4) offers a holistic view of the scholarly discourse of OSC research in PDR, highlighting which themes have been most prevalent and how the discourse has evolved. From an initial pool of over a thousand distinct keywords across the 113 publications, roughly fifty high-frequency (Freq=3) keywords meet the inclusion threshold of three times frequency to form a network visualisation (refer to Figure 3 (a)).

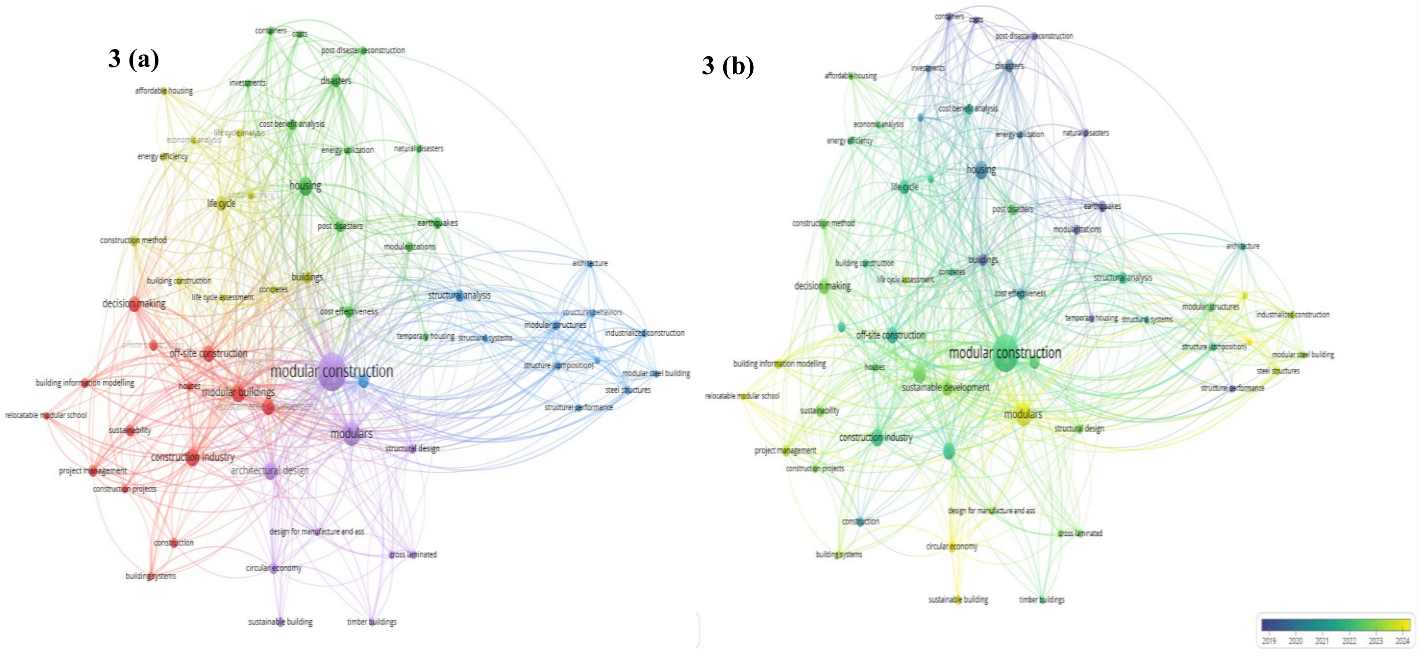

Figure 3: Keywords co-occurrence map for the OSC research in PDR context; (a) network visualisation; (b) overlay visualisation.

Several thematic clusters emerge in this network, each cluster comprising tightly interconnected keywords that denote key research strands. Notably, three overarching themes stand out as focus areas of the literature: *modular construction*, *sustainability*, and *resilience*. The prominence of these clusters suggests that the technical and strategic merits of modular/off-site building methods, as well as considerations of long-term sustainability and hazard resilience, have been focal points driving the OSC-PDR research agenda.

Crucially, the keyword network in Figure 3 informs how tightly OSC research is coupled with the PDR of houses context. The most connected and frequent terms in the network are those directly related to disasters and reconstruction. For instance, keywords such as "*disasters*," "*post-disaster reconstruction*," and similar variations form the core hubs of the map, possessing the highest link strengths (i.e. they co-occur with many other terms). This is evident in Figure 3(b), which shows OSC's robust associations with these disaster-related terms, underlining that nearly all discourse in this field is anchored to the post-disaster context. Figure 4 zooms in on the networks surrounding these pivotal terms: for instance, in the sub-network for "*disasters*" (Figure 4(a)), one observes strong links connecting the disaster theme to practical OSC concepts like "*modular construction*," "*modular buildings*," and "*housing*." Such linkages reveal that a significant portion of research has focused on leveraging modular/off-site building techniques to address the pressing needs of housing reconstruction after disasters. Similarly, the sub-network for "*post-disaster reconstruction*" (Figure 4(c)) is richly connected with OSC-related terms, reaffirming that off-site construction is increasingly seen as integral to modern reconstruction strategies.

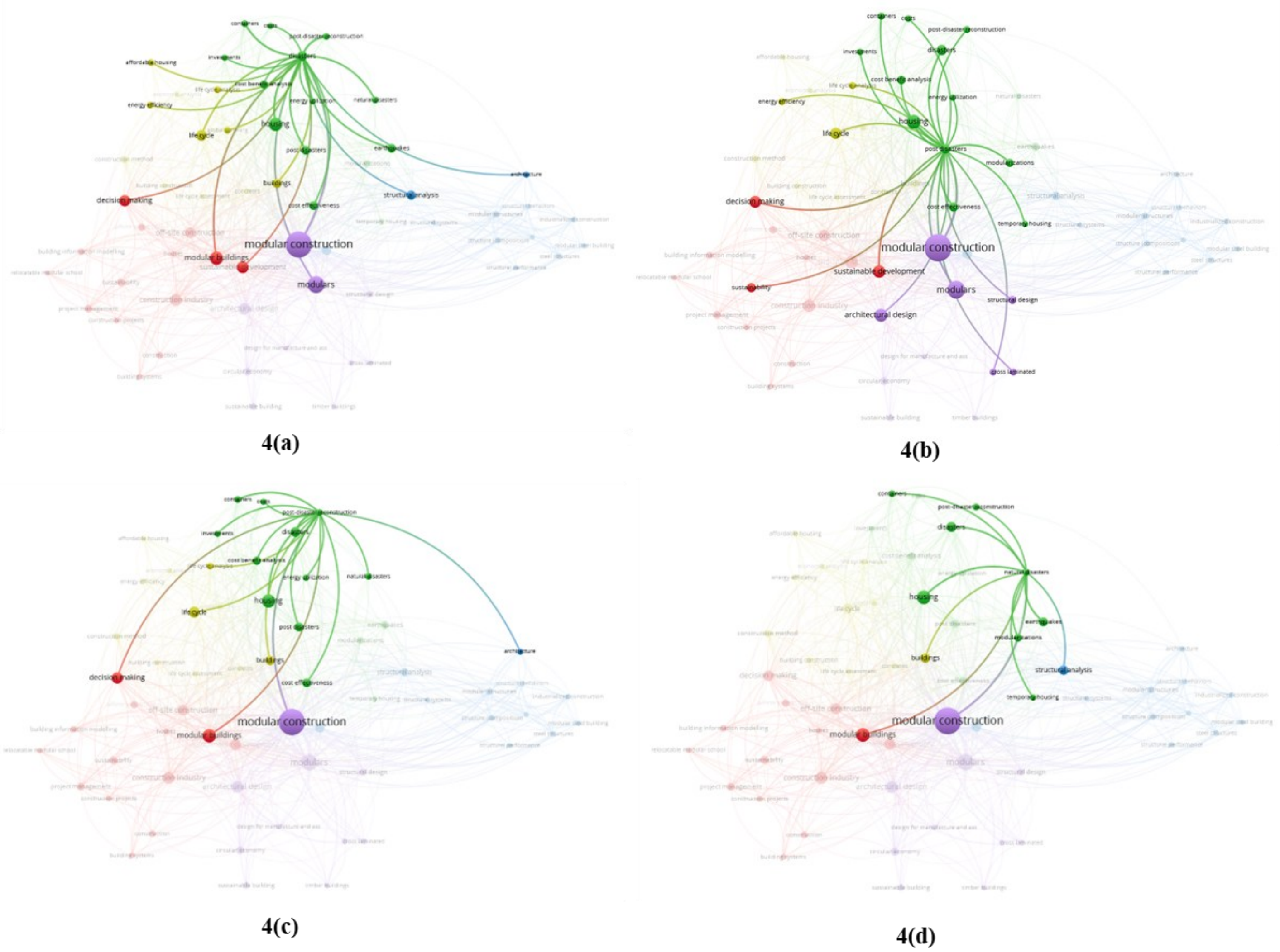

Figure 4: The keywords co-occurrence map of: (a) disasters; (b) post disasters; (c) post disaster reconstruction; (d) natural hazards

The ***evolution of research priorities over time*** is reflected in the changing weight and connectivity of certain keywords. Early in the timeline (mid-2000s), the literature appears to have centred on immediate, logistics-driven concerns – for instance, delivering temporary housing or expediting construction to shelter affected populations. As the field progressed into the 2010s and beyond, the vocabulary of research broadened. Terms related to sustainability and resilience grew more prominent, indicating a shift from purely rapid deployment of OSC towards ensuring that rebuilt communities are safer, greener, and more durable in the long run. This temporal shift, captured by the VOS viewer overlay analysis (Refer to Figure 3(b)), suggests that the academic discourse has matured: recent studies place greater emphasis on the quality and longevity of off-site solutions (e.g., energy-efficient modular units, resilient design for repeat hazards) rather than solely on speed and efficiency. In parallel, we see the emergence of keywords hinting at innovation and integration – for instance, concepts adjacent to OSC like circular economy or building information modelling (BIM) start appearing as the field interfaces with advancements in construction practice. Such developments point to a research domain that is not only expanding in volume but also deepening in complexity, connecting with broader trends in construction and disaster management.

Another notable pattern in the co-occurrence map is the ***disparity in thematic density between technical and socio-cultural facets of OSC in PDR***. The clusters around engineering and construction-process terms are highly populated and interconnected, reflecting intensive study and a possibly high degree of saturation in those areas. By contrast, keywords that would signify social, community, or policy-oriented aspects (i.e., "community engagement," "policy frameworks," or "governance") are relatively sparse in the network, if present at all. This gap implies that while the engineering and operational benefits of off-site construction have been well documented in the literature, the softer dimensions – such as community acceptance, cultural fit of prefabricated housing, and integration of OSC into policy and institutional arrangements – have not yet received equivalent attention. The current map therefore not only charts what has been extensively studied but also reveals under-explored niches that persist. The lack of dense clusters for these social dimensions highlights an opportunity for future research to balance the discourse, as the field moves toward a more holistic understanding of OSC's role in post-disaster recovery.

4. FINDINGS OF THE SYSTEMATIC REVIEW

While the scientometric analysis offers an overview of thematic structures and publication trends, it does not capture the nuanced content of the existing literature (Rathnasinghe et al., 2024). To address this limitation and enhance the analytical depth, a systematic review was conducted. This review aimed to critically synthesise empirical findings and theoretical insights concerning the use of OSC in PDR of houses. The analysis focused on two central areas: (1) the documented advantages of OSC, and (2) the key challenges or barriers impeding its effective implementation in disaster settings.

4.1 ADVANTAGES OF OFFSITE-CONSTRUCTION IN PDR

The literature reveals a broad consensus on the benefits of OSC, particularly in time-sensitive and resource-constrained post-disaster contexts. As shown in Table 2, these advantages span four main categories: time management, financial efficiency, construction quality, and sustainability.

Table 2: Advantages of using OSC in post disaster reconstruction of houses.

Categories	Advantages	Description	Sources
Time Management	Faster deployment	Enables quick response in emergency reconstruction contexts	[1] [2]
	Time intervals are shorter	Minimises the total project timeline from initiation to completion	[3] [4]
	Parallel construction	Allows simultaneous site preparation and module fabrication	[5] [6]
	Reduced weather delays	Indoor fabrication is less susceptible to adverse weather conditions	[7] [8]

Categories	Advantages	Description	Sources
Financial	Savings on expenses	Lowers long-term project costs through efficiency and standardisation	[1] [2] [3]
	Provide low-cost mass housing	Supports affordable housing scale-up for large, displaced populations	[2] [10]
Quality	Error reduction	Improves precision through factory-controlled processes	[11]
	Enhanced component customisation	Allows design flexibility within modular production constraints	[12] [13]
	Improving productivity and performance	Streamlines construction activities through process optimisation	[9] [14]
Sustainability	Mitigation of environmental impacts	Reduces on-site pollution and supports greener construction practices	[6] [15]
	Enhanced material reuse and recycling	Promotes circular economy through planned material recovery	[4] [15]
	Promotes health and safety	Minimises on-site risk by shifting work to safer factory environments	[9] [13]
	Labour-intensive activities reduction	Reduces reliance on large on-site workforce	[4] [16]

Sources: [1] (Gibb & Isack, 2003) [2] (Aburas, 2011) [3] (Hwang et al., 2018)[4] (Xu et al., 2020) [5] (Wong et al., 2017) [6] (Kamali & Hewage, 2016) [7] (Schuldt et al., 2021) [8] (Lu, 2009) [9] (Abanda et al., 2017) [10] (Pan & Goodier, 2012) [11] (Pan et al., 2012) [12] (Nawari, 2012) [13] (Liu et al., 2021) [14] (Kamali & Hewage, 2016) [15] (Jang et al., 2021) [16] (Razkenari et al., 2020)

One of the most cited and strategically significant advantages is the capacity of OSC to accelerate construction delivery (Aburas, 2011; Gibb & Isack, 2003). In humanitarian settings, reducing time to occupancy is a critical metric of success, particularly where vulnerable populations face prolonged displacement (Shahzad et al., 2022). These expedited timelines are critically beneficial within post-disaster scenarios, directly addressing the urgent need for rapid rehousing to mitigate prolonged displacement and community destabilisation (Rathnasinghe et al., 2021).

Studies such as Rapone et al (2024) have demonstrated the reuse potential of modular units with advanced building envelopes, enabling not only immediate shelter provision but also adaptable responses in repeated disaster cycles. Additionally, OSC's process efficiency translates into tangible environmental benefits through reduced waste, controlled emissions, and safer working conditions—hallmarks of sustainable recovery models.

4.2 CHALLENGES AND LIMITATIONS OF OFF-SITE CONSTRUCTION IN PDR

Despite these strengths, the review also highlights a range of systemic and operational challenges that constrain the broader implementation of OSC in PDR of houses (Refer to Table 3). These are grouped into four overarching categories: technological constraints, workforce-related barriers, operational inefficiencies, and financial limitations. A critical issue emerging from the literature is the lack of interoperability between OSC systems and local planning or regulatory regimes (Gan et al., 2018; Wuni & Shen, 2020). Without design standardisation, logistics coordination, and clear performance frameworks, the efficiencies promised by OSC are often compromised. This logistical complexity is notably intensified following disasters, as damaged infrastructure, compromised transportation routes, and limited accessibility significantly elevate costs and operational challenges of module delivery and on-site assembly (Gan et al., 2018).

Table 3: Challenges of using OSC in post disaster reconstruction of houses.

Categories	Challenges/ Limitations	Description	Sources
Technological	Damage during transport	Modules may suffer from structural compromise in transit	[1] [2] [3]
	Inferior imports	Low-quality materials or units may undermine long-term durability	[4] [5] [6]
	Rigid for last-minute design modifications	Design changes in post-fabrication are limited or costly	[4] [5] [6]
	Absence of acceptable size and repetition options	Limits adaptability to site-specific needs	[3] [7]
	Early commitment from contractors	Requires upfront planning before full project scope may be clear	[8] [9]
	Inventory control challenges	Difficulty tracking prefabricated units during storage or shipping	[4] [5] [6]
Human Resource	Training for current professionals and courses for new entrances	Demands specialised upskilling in modular systems	[6] [9]
	Lack of competent and professional labour	Shortage of trained workforce hampers quality and speed	[4] [10]
	Inadequate incentives	Lack of policy or financial motivation for industry adoption	[3] [4]
Operational procedures	No standardised design	Fragmented design frameworks delay implementation	[4] [9]
	Lack of standards	Absence of regulatory benchmarks complicates compliance	[2] [3]
	Lack of logistics	Weak transport and storage networks hinder module delivery	[2] [9]
	Intense emphasis on lowest bid price	Cost-cutting undermines quality and innovation	[2] [9]
Financial	High capital expenses	Upfront costs for facilities and technology are substantial	[8] [10]
	Larger initial capital expenditure	Initial funding requirements can discourage uptake	[4] [10]
	Transportation costs	Modules/ panels are costly to move over long distances	[5] [9]

Sources: [1] (Boyd et al., 2013) [2] (Gan et al., 2018)[3] (Hwang et al., 2018) [4] (Lou & Kamar, 2012) [5] (Rahman, 2014) [6] (Aburas, 2011) [7] (Kamali & Hewage, 2016) [8] (Razkenari et al., 2020) [9] (Wuni & Shen, 2020) [10] (Gumusburun & Ay, 2021)

Furthermore, while the technological infrastructure for prefabrication has advanced considerably, the institutional and policy infrastructure to support its widespread application in disaster contexts remains underdeveloped. This results in a fractured implementation landscape, where innovation is often isolated and under-leveraged.

5. DISCUSSION OF FINDINGS

Drawing on both scientometric and systematic reviews, this section reveals the critical trajectories of OSC, with attention to its role in addressing urgent reconstruction needs and its constraints in enabling long-term, socially grounded recovery.

5.1 PERSISTENT GAPS AND STRUCTURAL CONSTRAINTS

Despite clear benefits, the effective deployment of OSC in disaster contexts continues to face substantial implementation and knowledge barriers. In theory, OSC holds transformative potential for disaster recovery—moving beyond simply rapid shelter provision towards sustainable, adaptable housing that can evolve with community needs, supporting both short-term relief and long-term recovery. However, realising this potential remains challenging due to persistent structural constraints. These include bureaucratic delays, inconsistent application of building codes, and a lack of standardised frameworks, all of which significantly diminish OSC's intended advantages of speed and coordination (Rahman, 2014). Operational difficulties related to procurement logistics, transportation, and on-site assembly are particularly under-explored, especially in disrupted infrastructure environments. Social limitations compound these technical issues. A majority of OSC interventions adopt top-down delivery approaches, marginalising local input and often disregarding cultural, spatial, and social contexts (Thurairajah et al., 2019). Consequently, although delivered units might satisfy technical specifications, they frequently fail to support psychosocial recovery effectively. Furthermore, research into the long-term performance and adaptability of modular structures within multi-hazard environments remains limited, casting uncertainty over their sustained resilience (Ginigaddara et al., 2023). Studies exploring the transition of temporary shelters into permanent housing solutions are notably lacking. Few assessments rigorously evaluate life-cycle costs, modular reuse potential, environmental impacts, or post-occupancy performance (Pan & Sidwell, 2011). At the policy level, the transformative potential of OSC remains under-realised. Currently, OSC is often treated merely as a technical fix rather than as a comprehensive and transformative reconstruction approach. Fragmented governance systems and the absence of pre-approved modular standards further restrict its scalability and long-term impact (Zhai et al., 2014).

5.2 INNOVATION PATHWAYS AND RESEARCH FRONTIERS

Recent research trends point toward promising developments that seek to address these limitations. Technologies associated with Industry 4.0—including digital twins, BIM-based DfMA, and AI-driven generative design—are being investigated for their potential to enhance project planning, design flexibility, and resource efficiency (Ginigaddara et al., 2023). Yet, their performance in chaotic, uncertain post-disaster conditions remains largely theoretical, with limited empirical validation to date. Sustainability and circular construction are also gaining prominence. Modular units embedded with renewable energy systems and reusable components are emerging as conceptual models, though current OSC literature continues to under-represent green design in practice (Abdul & El-adaway, 2020). At the material level, innovations such as seismic-resistant connections and high-performance composites are being trialled to improve the structural integrity of prefabricated buildings. However, these technologies require further testing across varied geographic and hazard contexts to establish their reliability and transferability. Overall, the future of OSC innovation within PDR lies not only in advancing isolated technological or material solutions but also in exploring the interdependencies between physical innovations (materials and modular technologies), information innovations (digital systems and data-driven methods), and cognitive innovations (stakeholder integration, policy alignment, and community-driven design). Therefore, future research should prioritise these integrated pathways, fostering comprehensive frameworks that leverage technological advancements while also emphasising adaptability, contextual sensitivity, and community resilience.

5.3 REPOSITIONING OSC IN THE LONG-TERM RECOVERY CONTINUUM

Of particular significance is a conceptual shift emerging in the literature: a rethinking of OSC housing across its lifecycle. Recent studies increasingly advocate for OSC, particularly modular systems that serve not merely as short-term shelters but as transitional assets capable of evolving into permanent infrastructure (Goulding & Rahimian, 2019). This direction calls for research into modular flexibility, participatory planning, and institutional arrangements that enable OSC to bridge the relief-to-recovery continuum. Taken together, these findings reinforce the view that the value of OSC in PDR cannot be assessed by construction speed or efficiency alone. As the study reveals, rapid deployment often comes at the cost of adaptability and local fit. Without mechanisms to embed OSC within broader recovery strategies, it risks delivering technically competent yet socially disconnected solutions. What emerges instead is the need for a paradigm shift: from viewing OSC as a logistical fix to understanding it as a platform for sustainable, inclusive reconstruction. The construction of housing units must not be conflated with the creation of homes. The latter requires design and delivery processes that are attuned to the lived realities of disaster-affected populations—supporting not only their immediate shelter needs but also their long-term recovery, identity, and community cohesion. This critical reframing of OSC will form the basis for the concluding section, which outlines the policy and research implications of treating OSC not as an end, but to support enduring, culturally responsive, and socially embedded post-disaster housing solutions.

6. CONCLUSION

This study underscores the rising prominence of OSC as a technically capable and logistically agile strategy in PDR. Yet, despite its operational strengths, OSC remains constrained by fragmented policy support, insufficient standardisation, and a persistent disconnect from the social realities of recovery. As it stands, OSC too often delivers structures, not solutions. If OSC is to serve as more than a temporary fix, it must be reframed as a transformative mechanism for recovery—one that not only addresses shelter deficits but actively contributes to rebuilding lives. This requires reimagining the modular unit not as an end-product, but as a platform for social continuity, cultural adequacy, and long-term resilience. In this light, the challenge is not to produce faster housing, but to co-create '*transformational homes*' that can evolve with the needs and aspirations of displaced communities. Only then can OSC realise its full potential as an enabler of sustainable, dignified, and future-oriented recovery.

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