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Review article

Design for Disassembly in Residential Buildings: A Systematic Review of Current Practices and Emerging Digital Technologies

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ABSTRACT

This systematic review critically examines the state of Design for Disassembly (DfD) in residential construction, synthesising evidence from 95 peer-reviewed studies and 71 case studies published between 2010 and 2025. The study asks: To what extent do current DfD strategies align with residential realities, and what integrated approaches are needed to bridge gaps in validation and assessment? Despite rapid growth in circular economy (CE) research, findings reveal a fundamental misalignment between the technical development of DfD strategies and the socio-spatial realities of housing. Firstly, while DfD offers critical capabilities for portability and rapid response to housing shortages and emergency contexts, current scholarship predominantly prioritises uncertain, scenario-based end-of-life waste recovery over these immediate functional benefits. Secondly, empirical research mainly focuses on low-rise dwellings, leaving mid- and high-rise buildings largely theoretical despite their significant material intensity. Thirdly, the economic frameworks and social dimensions of housing remain largely unexamined. To address these gaps, emerging digital technologies offer substantial potential. Specifically, machine learning can replace uncertain life cycle predictions with predictive circularity modelling, computer vision enables the digitisation of existing housing stock to quantify residual material values for alternative mortgage models, and large language models can address the social dimensions to increase the adoption of DfD and CE strategies among non-expert homeowners and self-builders. The review concludes that advancing residential DfD requires integrated research across all building scales, bridging technical, environmental, and socio-economic domains to achieve a scalable circular transition.

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1. INTRODUCTION

Design for Disassembly (DfD) has emerged as a fundamental strategy within the Circular Economy (CE), aimed at facilitating the recovery and reuse of building components to minimise resource depletion. The urgency to adopt such strategies is driven by the sheer scale of the construction industry's environmental footprint.

Globally, the building sector generates the largest share of waste, accounting for approximately 37–40% of

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the total output (Lausselet et al. 2023; Montalbano and Santi 2023; Oluleye et al. 2023) and 52% of the EU's material footprint (EEA 2024). Despite the Waste Framework Directive's target to recycle 71% of construction waste (European Commission 2018), actual EU recycling rates reached only 40.8% by 2022 (Eurostat, 2024). This urgency is compounded by the intrinsic nature of housing, where demographic shifts and changing occupancy needs drive a rapid 'churn' of interior spaces (Brand 1995). With three billion people projected to require new homes by 2030 (Çetin et al. 2021), implementing DfD is critical to ensuring this surge in construction does not follow current upward waste trends.

This strategic necessity aligns with The EU's Green Deal (2019) and is central to the EU's Circular Economy Action Plan (2020) both of which seek to harmonise regulatory frameworks and strengthen the circular construction market to ensure sustainability compliance. Although the transition towards circular construction is advancing, the existing research maintains a strong technical focus. This emphasis presents a challenge for residential architecture because it overlooks the social and economic factors that determine the actual lifespan of a home, including occupant habits, ownership structures, and market demands. Table 1 categorises the current literature on Design for Disassembly into four primary areas: prefabrication and modular construction, artificial intelligence and digital tools, environmental assessment barriers, and studies focused on specific structural systems or housing policies.

Table 1. Classification of existing systematic reviews on DfD and their primary research scopes.

Research Domain	Key Focus Areas	Representative Review Papers	Primary Scope
Prefabrication & Modular Construction	Timber Structures Prefabrication Modularity & DfMA	(Adekunle et al. 2024; David et al. 2024; Gutiérrez et al. 2024; Minunno et al. 2018; Roxas et al. 2023)	Investigates DfD through the lens of specific structural systems or production methodologies. The analysis centres on the physical properties of the material or the efficiency of off-site assembly processes.
Digitalisation and Technology Focus	Artificial Intelligence (AI)	(Oluleye et al. 2023)	Reviews the application of advanced digital tools in the construction industry. The scope is defined by the integration of data-driven technologies (such as AI algorithms) to optimise circular economy workflows.
Implementation Barriers, Guidelines & Standards	Industry-wide Barriers Design Guidelines Life Cycle Assessments (LCA) & Accounting Standards	(Charef et al. 2021; Kanters 2018; Kręt-Grześkowiak and Baborska-Narożny 2023; Lausselet et al. 2023; Majmundar and Ansari 2018; Roberta Carvalho Machado et al. 2018)	The scope includes identifying barriers, evaluating design guidelines, and reviewing environmental accounting standards.
Sector-Specific Analysis	Built Structures Social Housing Policy	(Gomide et al. 2024; Ostapska et al. 2024)	Ostapska et al. (Ostapska et al., 2024) analyses a dataset of built structures based on technical taxonomies, while Gomide et al. (2024) focuses specifically on policy frameworks within the social housing sector.

However, this classification reveals that existing reviews primarily focus on structural systems or technological tools, largely overlooking typology-specific challenges. This technical focus overlooks the unique temporal and social dynamics of housing, where patterns of occupancy, lifestyle shifts, and demographic turnover drive a rapid transformation of interior 'shearing layers.' These residential-specific pressures challenge the applicability of generic DfD principles derived from static industrial or commercial contexts.

Therefore, this research asks: To what extent do current DfD strategies align with residential realities, and what integrated approaches are needed to bridge gaps in validation and assessment? The study critically interrogates the current body of knowledge to expose the structural and methodological disconnects hindering the scaling of DfD in the residential sector.

Consequently, this research departs from the prior reviews categorised in Table 1 by shifting the analytical focus away from their conventional technical parameters. While existing DfD, CE, and modularity reviews predominantly evaluate end-of-life waste recovery or structural properties, this study establishes a distinctly residential lens. It explicitly adds what these prior reviews overlook within the context of DfD and CE frameworks: the occupant perspective, the necessity of alternative mortgage models, the potential for rapid-response emergency shelters, and the critical need for everyday spatial adaptability. Furthermore, rather than treating artificial intelligence merely as a generic digital tool, as seen in existing AI-focused reviews, this paper explores how emerging AI can specifically resolve these housing-centric challenges through targeted applications such as predictive circularity modelling via machine learning, automated disassembly sequencing using reinforcement learning, material recognition for existing stock through computer vision, and the facilitation of knowledge transfer for self-builders via large language models.

2. MATERIALS AND METHODS

This systematic literature review (SLR) was carried out in strict compliance with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) protocol. The research design followed a structured five step process comprising database identification, title and abstract screening, full text eligibility assessment, citation analysis, and thematic coding, as illustrated in Figures 1 and 2.

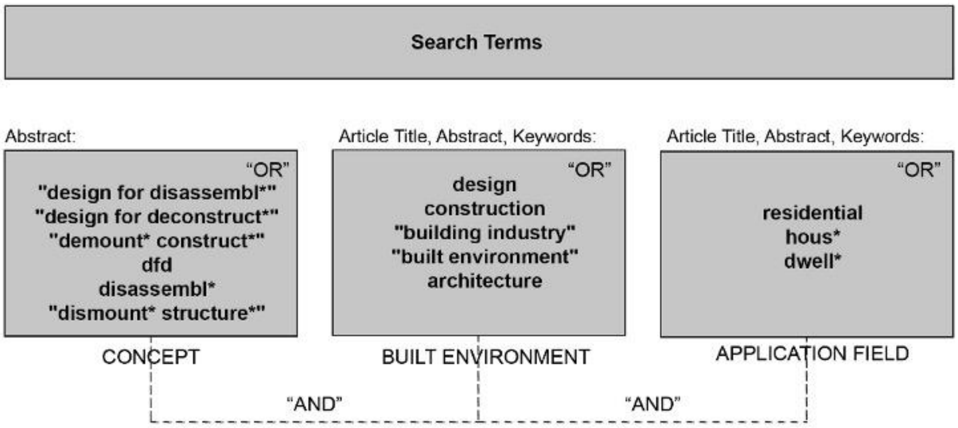


Figure 1. Construction of the search query.

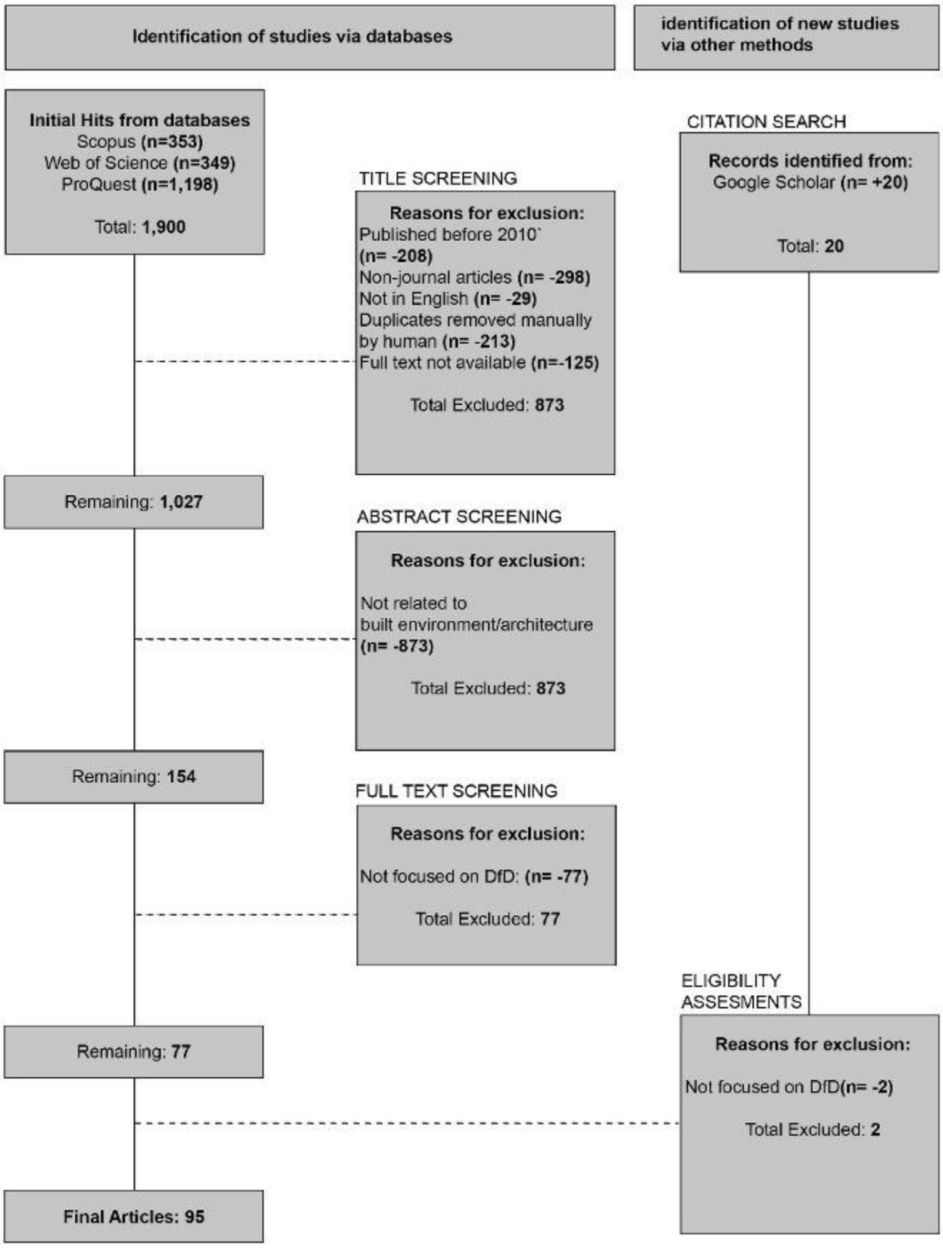


Figure 2. PRISMA Flowchart for selected articles.

2.1. *INCLUSION AND EXCLUSION CRITERIA*

The initial literature search was conducted in December 2025 across three primary databases: Scopus, Web of Science, and ProQuest. To capture the intersection of DfD and the residential sector, a specific search query was applied to the title, abstract, and keywords, as detailed in Figure 1. The search was restricted to English language journal articles published between 2010 and 2025. This timeframe was specifically selected to capture the modern era of intensified digital adoption, such as Building Information Modelling maturity, and the introduction of contemporary circular economy policies.

Following the retrieval of the initial results, all records were imported directly into NVivo software, where duplicate entries were identified and removed manually. The unique articles were then subjected to a two-stage screening process. First, titles and abstracts were reviewed to exclude publications that were not peer reviewed journal articles and studies unrelated to the built environment. Second, the full texts of the remaining articles were retrieved and evaluated against the inclusion criteria. Studies were excluded at this stage if their primary focus did not explicitly address Design for Disassembly strategies or circular construction principles.

To ensure a comprehensive dataset, backward and forward citation analyses were conducted on the selected full text articles using Google Scholar to identify any relevant literature missed by the primary database search.

This process yielded an additional 18 relevant journal articles. Ultimately, as illustrated in Figure 2, 95 articles were deemed eligible and formed the final dataset for this review.

2.2. THEMATIC CODING AND DATA ANALYSIS

To systematically evaluate the 95 selected articles, a thematic coding analysis was conducted using NVivo software. An inductive coding approach was adopted, allowing key themes, barriers, benefits, research gaps, and methodological trends to emerge directly from the literature. The coding process structured the qualitative data into a hierarchical framework comprising primary themes and targeted subthemes. For instance, artificial intelligence was identified as a primary theme, with potential application areas emerging as specific subthemes based on the literature content.

To provide full transparency of this analysis, the exported NVivo codebook is provided as supplementary material. This supplementary document details the entire hierarchical thematic framework, identifying the coding frequencies for each category. Specifically, it lists the primary themes and subthemes alongside the exact number of unique articles in which they were coded, as well as the total volume of words and sentences highlighted across the dataset. Following this data extraction, a comparative synthesis was performed to structure the results and discussions regarding the implementation of DfD in residential contexts.

2.3. CLASSIFICATION FRAMEWORK AND CODING RELIABILITY

To address the categorisation of case studies and ensure methodological transparency, an explicit coding framework was developed. This framework established specific decision rules for classifying both the residential relevance and the validation methods of the included literature (see Table 2).

Table 2. Description of case study types.

Case Study Type	Description
Physical Models	Validation through constructed physical artefacts, ranging from full-scale buildings (houses, pavilions) to prototypes.
Digital Models	Validation through computational environments, utilising BIM, AI, or parametric simulations without physical construction.
Hybrid Models	Combined Validation: Studies that integrate both physical prototyping and digital simulation to verify performance.
Existing Project/s	Analysis of completed, real-world buildings (Post-Occupancy or Deconstruction analysis).
Physical /Digital / Hybrid Component Models	Studies analysing component-level building elements (e.g., modular wall systems, joints, or façade elements) by constructing physical and/or digital models/prototypes.

Residential relevance was classified into four distinct categories. 'Primary Focus' designated studies explicitly investigating circular strategies within residential environments. 'Related' categorised studies examining general architectural applications with direct residential crossover. 'Adaptable to Residential' captured structural systems designed for non-residential typologies, such as temporary pavilions or commercial spaces, that possess clear structural transferability to housing. Studies marked as 'Not Related' were evaluated solely to establish comparative baseline metrics regarding general disassembly principles.

Furthermore, the methodological validation of the proposed systems within these case studies was categorised based on their testing environments. 'Digital Models' designated research relying entirely on computational simulations, such as Building Information Modelling or algorithmic life cycle assessments. 'Physical Models' involved the construction of tangible prototypes or real-world material mock ups. 'Hybrid Models' integrated both computational simulation and physical construction to validate findings. 'Component Models' captured studies analysing component level building elements, such as modular wall systems, joints, or facade elements, through the construction of physical, digital, or hybrid prototypes. Finally, 'Existing Projects' involved the post occupancy evaluation or material analysis of already constructed buildings.

While the classification of studies occasionally involved a degree of interpretation, a structured protocol was employed to ensure coding reliability. Specifically, the primary author conducted the initial categorisation of all included studies. To mitigate individual bias, a secondary author independently cross checked a representative subset of the dataset. Any subjective discrepancies between the reviewers were resolved through discussion and a detailed reassessment against the established classification criteria. Furthermore, to guarantee complete transparency and reproducibility, a comprehensive classification spreadsheet detailing how every included study was categorised across all dimensions is provided as supplementary material.

3. RESULTS

3.1. PUBLICATION TRENDS AND GEOGRAPHICAL DISTRIBUTION

Analysis of the selected studies reveals a significant acceleration in circular design research over the last decade (see Fig. 3). As illustrated in Fig. 4, this trajectory aligns with the introduction of major policy frameworks, most notably the EU's Circular Economy Package (2015) and the subsequent Circular Economy Action Plan (2020).

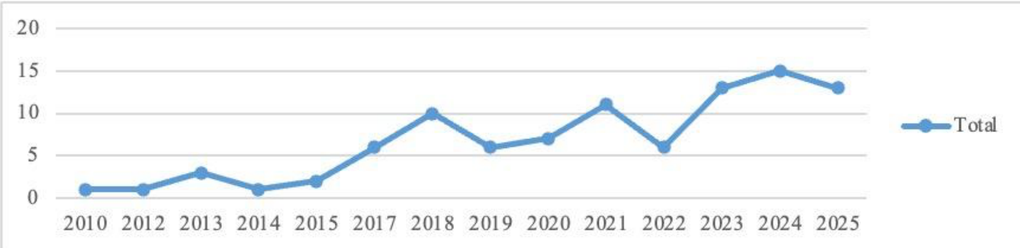


Figure 3. Cumulative publication trend shows a noticeable increase after 2015 aligns with EU policy changes.

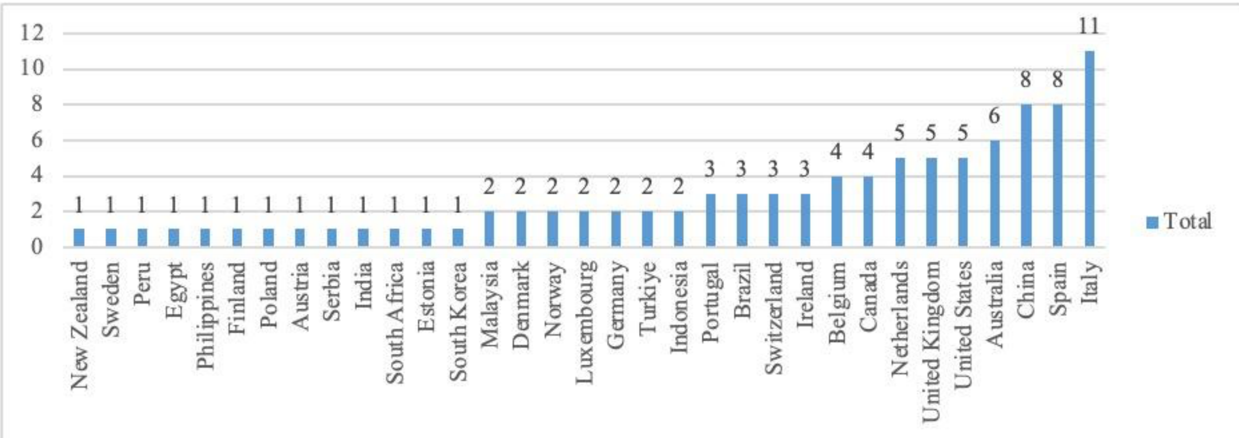


Figure 4. Number of publications by country.

The data indicates that Europe dominates the research landscape, accounting for 59% of the selected publications (see Fig. 5).

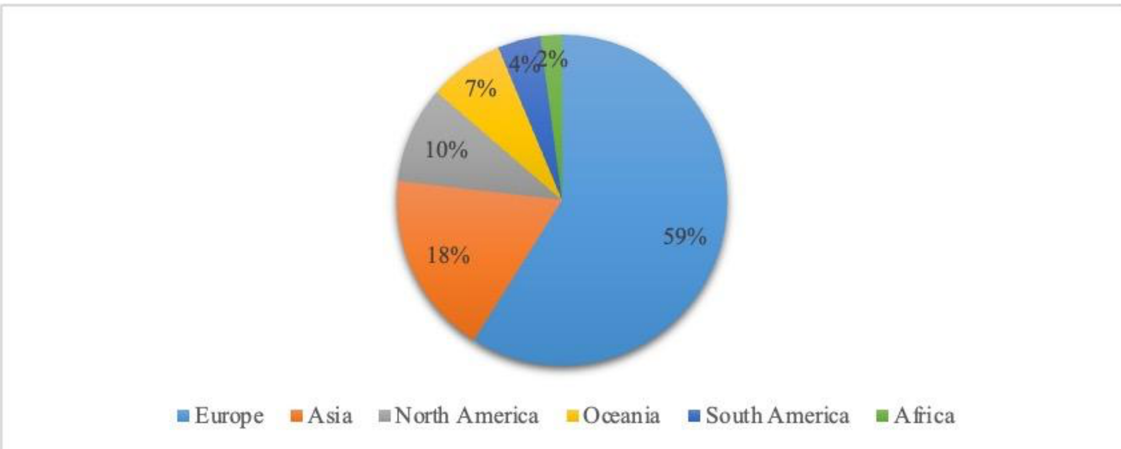


Figure 5. Publications per continent.

3.2. PREDOMINANT RESEARCH METHODOLOGIES

Case studies are the most common methodology in the reviewed articles, accounting for 71 of the 95 selected studies (74%). As illustrated in Figure 6, the dominance of this method within DfD research has continued to grow over time.

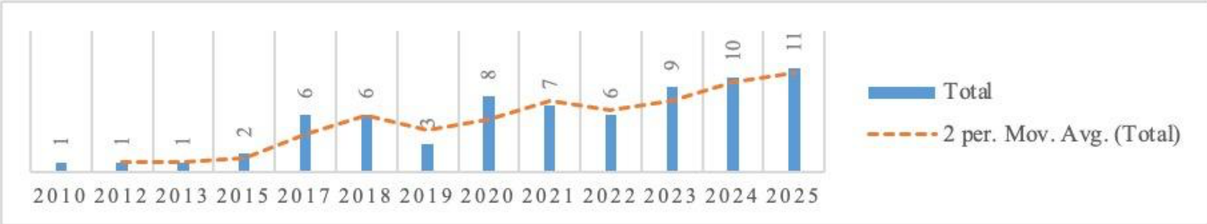


Figure 6. Distribution of the 71 Case Studies Published by Year.

3.3. ANALYSIS OF CASE STUDIES

3.3.1. BUILDING SCALES AND RELEVANCE TO RESIDENTIAL CONTEXTS

As noted in the review by David et al. (2024), the majority of DfD studies focus on low-rise residential buildings. This trend is also evident in the present review (see Fig. 7). Of the 71 case studies, 66% (47 studies) focus exclusively on low-rise buildings, with the majority 76% (36 out of 47) explicitly addressing residential contexts.

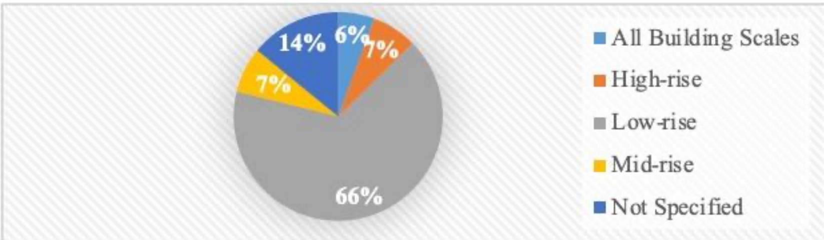


Figure 7. Building scales of case studies.

In contrast, the number of studies investigating mid- and high-rise buildings is relatively low, accounting for only 7% of the total reviewed studies. A further 6% of studies investigate all building scales, while the remaining 14% of studies do not specify a building scale, focusing instead on component-level analysis (e.g., specific connection types or materials).

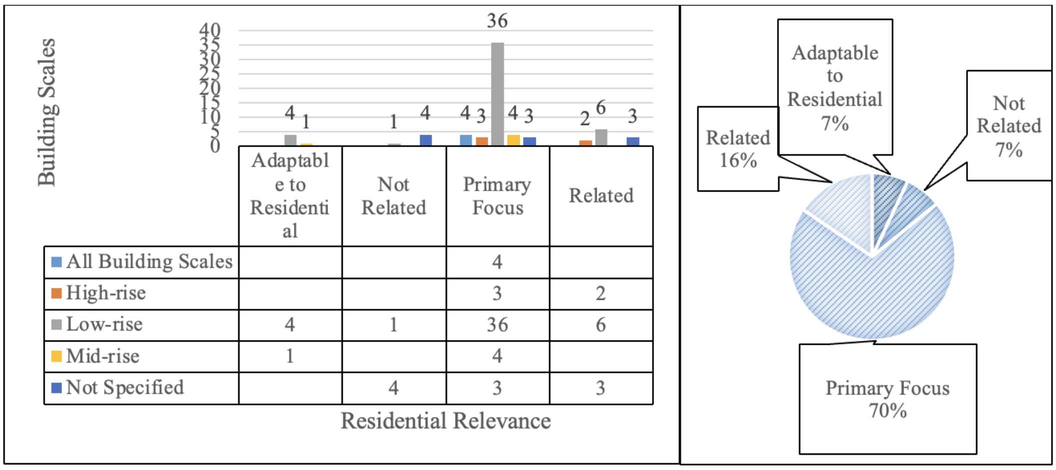
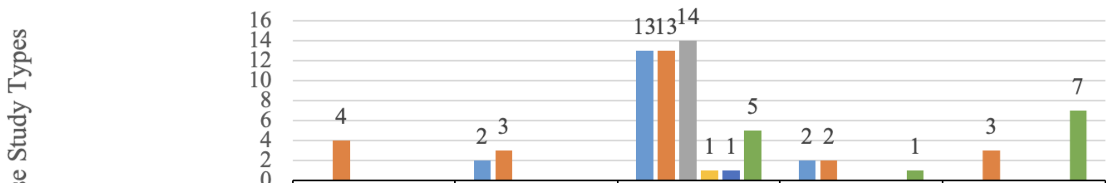


Figure 8. Residential relevance of case studies by building scales.

To ensure a comprehensive review, Figure 8 classifies studies based on their direct applicability to housing. While 70% (36 low-rise; 4 mid-rise; 4 all building scales; 3 high-rise; 3 not specified) focus primarily on residential buildings, 16% (6 low-rise; 3 not specified; 2 high-rise) fall into the 'Related' category, signifying that they revolve around generic contexts such as commercial or public buildings that offer direct insights for residential application. A further 7% (4 low-rise; 1 mid-rise) are deemed 'Adaptable' due to their universal methodological focus, while only 7% (4 not specified; 1 low-rise) are classified as 'Not Related' (pavilions/non-residential), included solely for their unique technical contributions.

3.3.2. CATEGORISATION OF VALIDATION METHODS

To analyse the robustness of DfD proposals, the case studies are categorised based on their validation methodology. As detailed in Table 2, the classification distinguishes between theoretical (Digital), empirical (Physical), and combined (Hybrid) validation strategies.



Building Scales	All Building Scales	High-rise	Low-rise	Mid-rise	Not Specified
Digital Models		2	13	2	
Existing Project/s	4	3	13	2	3
Hybrid Models			14		
Neighbourhood Project			1		
Physical Models			1		
Physical /Digital / Hybrid Component Models			5	1	7

Figure 9. Categorisation of case study types by building scales.

Figure 9 reveals a distinct gap in how the reviewed studies validate DfD strategies across different building scales. Hybrid models are only used for low-rise buildings, accounting for 14 studies. Mid- and high-rise buildings lack this hybrid validation completely. Instead, research into denser buildings is limited to digital models. Other studies simply analyze existing projects across various building and component-level scales.

3.3.3. KEY RESEARCH FOCUS AREAS

The selected case studies have been classified according to their primary research objectives to highlight dominant trends and critical gaps. This framework identifies five distinct areas of focus, ranging from theoretical design proposals to empirical life cycle assessments (see Table 3).

Table 3. Taxonomy of Research Focus Categories.

Research Focus Category Names	Goal & Scope
Innovation through Design & Building System Proposal	● Scope: Proposes new concepts, methods, or building technologies. ● Goal: To improve DfD practices through novel architectural configurations.
Practical Applications and Evaluation of DfD	● Scope: Examines existing projects, assessing connections and systems in situ. ● Goal: To highlight the practical benefits and challenges of DfD in various material-specific contexts.
Environmental Impact & Assessment Tools	● Scope: Includes research that assesses the environmental footprint and circularity potential of building materials, construction processes, or building life cycles such as LCA or LCC.

Research Focus Category Names	Goal & Scope
Innovation through Deconstruction Method Proposal	● Goal: To quantify resource efficiency and closed-loop potential. ● Scope: Includes articles that propose new or improved deconstruction methods. ● Goal: To enhance the efficiency, sustainability, or safety of building deconstruction.

The research landscape is polarised into two dominant domains: 'Innovation through Design' and 'Environmental Impact & Assessment Tools' (see Figure 10).

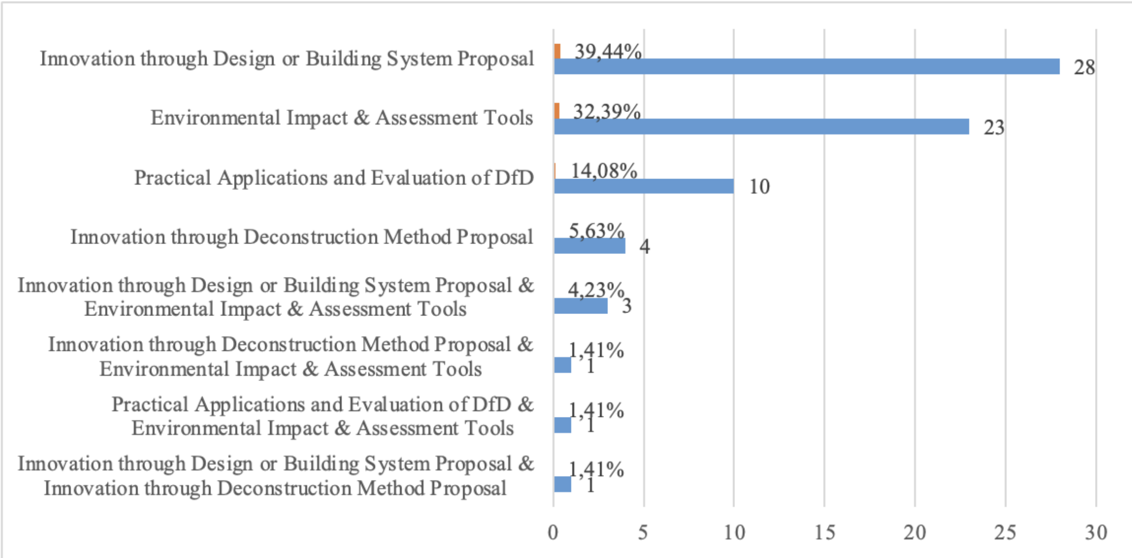


Figure 10. Total Research Focus Categorisations.

Only three studies integrate environmental assessments with innovative building system proposals. 'Practical Applications and Evaluation' follows as the third most common focus with 10 studies. Finally, deconstruction method proposals are noticeably scarce.

Within the category of 'Innovation Through Design & Building System Proposals', the analysis adapts to address the disparity in research volume. Given the high concentration of case studies at the low-rise scale, the review prioritises studies utilising hybrid models, as combining physical and digital testing yields significantly deeper insights into constructability and performance.

In contrast, the mid- and high-rise buildings are characterised by a scarcity of hybrid models. Despite the limited number of studies (4 mid-rise, 1 high-rise), these digital proposals are examined to capture the current theoretical frontier of mid- and high-rise DfD. Figure 11 maps the main research areas and subtopics reviewed in the study. The green highlighted boxes show the specific topics covered in this review, while the white ones in the low-rise section indicate the topics that are excluded.

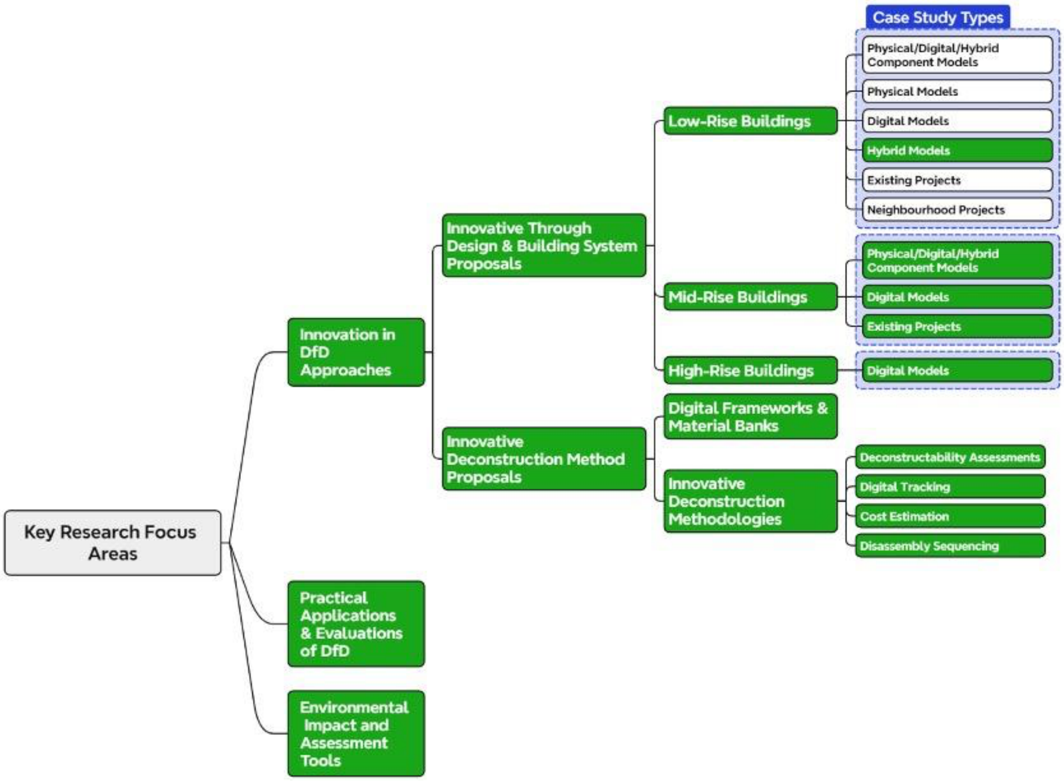


Figure 11. Key research focus areas & roadmap for the next sections.

3.3.3.1. *INNOVATION IN DFD APPROACHES*

A significant proportion of the selected literature focuses on innovation. The review distinguishes two primary streams of development: proposals for novel building systems and the proposal of novel deconstruction methodologies. While building system proposals prioritise the integration of reversibility during the architectural design phase to facilitate future recovery, methodology proposals focus on the operational aspects—such as tools, sequencing, and technical processes—required to dismantle structures.

3.3.3.1.1. *INNOVATION THROUGH DESIGN & BUILDING SYSTEM PROPOSALS*

Across these scales, modularity and prefabrication emerge as fundamental DfD principles, aligning with established guidelines by Crowther (1999). However, a clear typological divide is evident in the application of these principles: innovation in low-rise housing is characterised by the development of novel, lightweight structural systems, whereas innovation in mid-to-high rise typologies focuses on retrofitting and component-level modularity.

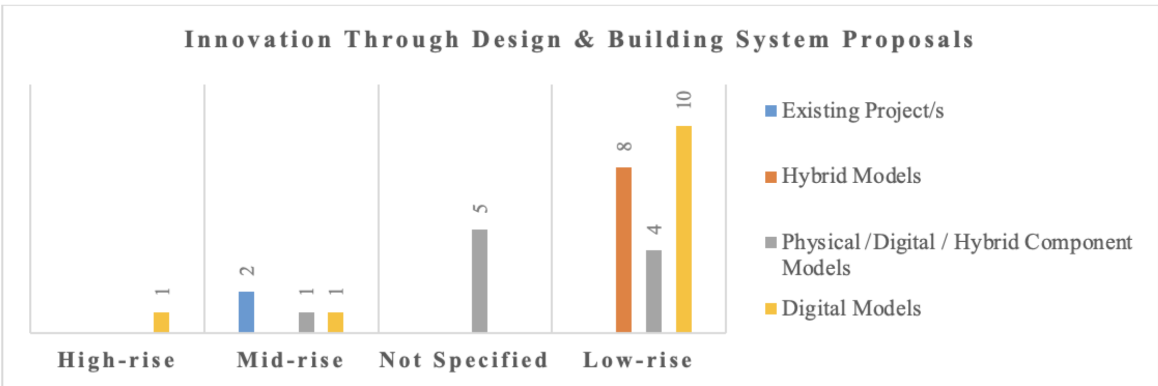
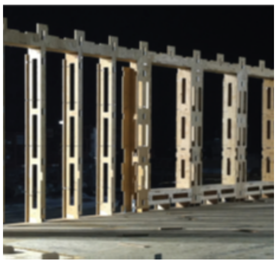
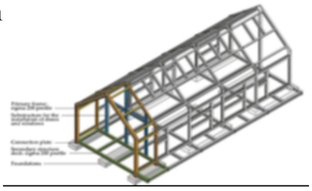
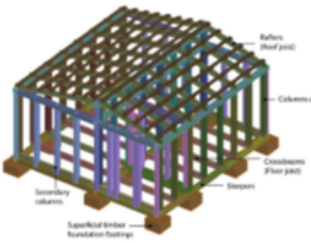
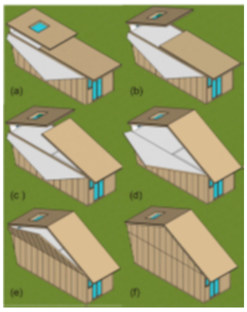
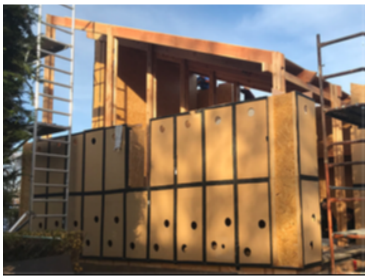
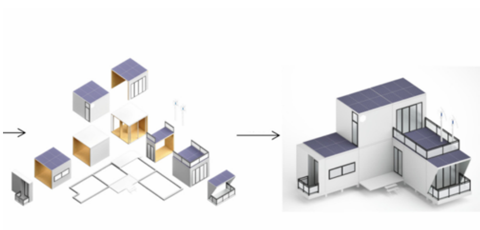


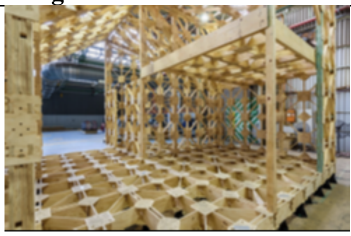
Figure 12. Case study types in Innovation through design & building system proposals

- Low-Rise Buildings: Total of 22 studies focus on innovative building proposals. To ensure a rigorous evaluation, the analysis only prioritises the studies utilising hybrid models (8 studies). This core dataset is further enriched by three additional industry case studies identified from the reviewed studies—WikiHouse from (Priavolou 2018), B.R.I.C. from (Piccardo and Hughes 2022), and X-Frame from (Finch et al. 2021). These systems adopt CE principles through reversible, low-waste strategies.
  Low-rise research is dominated by discrete, open-source modular systems driven by digital fabrication (Figure 12). Except for the robotic cork construction by Wilton & Howland (2020), prominent examples such as Sim[PLY] (Albright et al. 2017), WikiHouse (Priavolou 2018), and X-Frame (Finch et al. 2021) share a common tectonic logic utilising CNC-cut plywood with adhesive-free interlocking connections. This ensures components remain uncontaminated and fully recoverable (see Table 4).
  Beyond engineered products, research explores alternative material strategies. The EU-funded 'Buildings as Material Banks' (BAMB) pilot project B.R.I.C. (Capelle et al. 2019; Piccardo and Hughes 2022) investigates salvaged timber frames to close material loops. Non-timber approaches focus on lightweight steel modular systems (Salvalai et al. 2020; Violano and Cannaviello 2022; Wang et al. 2025). Notably, Wang et al. (2025) differentiate their proposal through a comprehensive quantitative analysis; unlike other conceptual models (Salvalai et al. 2020; Violano and Cannaviello 2022), they explicitly benchmark reductions in material, labour, and costs against conventional steel structures to demonstrate practical viability. Differently, Resta & Gonçalves (2024) explore the reversibility of precast concrete modules. Despite this material diversity, a common objective unifies these proposals: reducing embodied carbon while ensuring components remain modular and mechanically connected for future retrieval.
  The portability and speed of these dry-assembly systems have driven their application in urgent societal contexts, particularly emergency and temporary housing. Studies by Asmat et al. (2022) and Pérez-Valcárcel et al. (2024) explicitly leverage the modular nature of DfD to propose rapid-response shelters for natural disaster scenarios. However, the alignment between DfD principles in emergency housing remains a significantly underexplored area.

Table 4. Images of the reviewed building systems (Hybrid Models).

Building System & Ref.	Images
Cork Construction Kit (Wilton and Howland 2020)	 
Sim[PLY] (Albright et al. 2017)	 
GOMOS modular system (Resta and Gonçalves 2024)	 

Building System & Ref.	Images	
"Petite-Cabane" system (Violano and Cannaviello 2022)		
"Delight the Light" system (Salvalai et al. 2020)		
Temporary Dwelling (Asmat et al. 2022)		
Experimental Prototype (Pérez-Valcárcel et al. 2024)		
WikiHouse ("WikiHouse Webpage Projects" 2022)		
B.R.I.C. (Piccardo and Hughes 2022)		
M-Box1.0 (Wang et al. 2025)		

Building System & Ref.	Images
X-Frame ("X-Frame System" n.d.)	 

- Mid-Rise Buildings: Innovation in the mid-rise category (4 studies) represents a paradigm shift from the "invention" focus of low-rise systems to a pragmatic strategy of substitution and adaptation. Unlike the tabula rasa approach of lightweight prototypes, these studies focus on the density and seismic demands of existing urban fabrics, investigating how DfD principles can be reconciled with high-mass structural requirements.
  A primary trend involves the application of steel-timber and concrete to this scale. For example, Morales-Beltran et al. (2023) develop a Cross Laminated Timber (CLT)-steel frame that balances the low-carbon benefits of timber with the ductility required for seismic zones. Through LCA, they demonstrate that such a combination offers a robust environmental alternative to traditional concrete while maintaining structural integrity. Similarly, Errante and de Capua (2021) apply this steel-timber combination approach to the retrofitting of public housing, proposing an additive steel framework integrated with 'Bio-XLAM' modules—a dry-assembled timber technology that eliminates the need for adhesives. Both approaches strategically extend the functional lifespan of obsolete stock.
  In contrast to the steel-timber combination, other 2 studies focus on concrete but fundamentally alter its application to enable reversibility. Djukanovic et al. (2025) propose a mid-rise system composed of modular precast concrete panels. By prioritising user-specific spatial configurations, this model transforms the static concrete shell into a flexible framework capable of expansion and disassembly. Conversely, Halding (2023) targets the chemical bond itself. Rather than relying on dry mechanical connections, the study proposes a weak lime-cement mortar designed to facilitate the non-destructive disassembly of precast slabs. This method introduces reversibility into high-rise construction without eliminating wet trades.
  Reflecting the increased structural risk and cost associated with this scale, the validation strategies in these studies differ markedly from the full-scale prototyping seen in low-rise research. Validation relies on digital simulation (e.g., seismic modelling) or isolated component testing rather than whole-building construction.
- High-Rise Buildings: Innovation in high-rise residential buildings (1 study) remains the least developed area of DfD research, characterised by a conceptual design.
  Ferreira Silva et al. (2020) propose digital prototypes for modular high-rise units to address housing shortages. While these units apply the "kit-of-parts" logic seen in low-rise systems to a vertical typology, the authors acknowledge that the proposal lacks detailed structural analysis.
- Experimental Innovations: Beyond building-scale studies, five studies (Cui et al. 2023; Dahy 2019; J.C. Gómez and Martínez 2017; Nathansohn et al. 2020; Tepavčević et al. 2017) explore DfD through experimental pavilions and parametric structures. These case studies function as technological incubators, utilising parametric design tools to test complex geometries and novel biomaterials that are not yet viable for standard housing. Other studies such as (Daly 2025; Zanni et al. 2021) focus on novel modular retrofitting systems on existing buildings to enhance the structural and thermal performances.
  While not strictly residential, these experiments validate the potential of digital fabrication to democratise construction. Notably, Nathansohn et al. (2020) and Tepavčević et al. (2017) highlight how high-tech fabrication methods—such as robotic assembly— can be adapted for low-cost housing experiments.

3.3.3.1.2. Innovative Deconstruction Method Proposals

Six studies involve innovative deconstruction methods; most of them (3 studies) focus on existing projects in low-rise buildings to apply their proposals, and 2 studies analyse the applicability of deconstruction methods.

The analysis reveals that efficient deconstruction relies on two distinct pillars: Digital framework of materials and disassembly methods.

1. Digital Frameworks and Material Banks: A recurring finding is the necessity of securing end-of-use data to close the material loop. To achieve this, the literature distinguishes between theoretical management concepts and specific data architectures. Cai and Waldmann (2019) propose the 'Material and Component Bank' as a comprehensive management method for tracking, certifying, and storing reusable components.
   Parallel to this theoretical work, other studies identify specific digital enablers required to operationalise these banks. Çetin et al. (2021) classify 'Material Passports' as one of ten essential technologies for a circular built environment. These passports often rely on protocols established by major initiatives; for instance, the BAMB project is frequently cited (Çetin et al. 2021; Kręt-Grześkowiak and Baborska-Narożny 2023; Walsh and Shotton 2024; Yan et al. 2022), as a foundational framework for reversible building design data.
2. Innovative Deconstruction Methodologies: Building on these information repositories, 6 studies propose operational methodologies to optimise the execution of deconstruction. While Material Passports identify what is in the building, these proposals focus on how to remove it, targeting four specific technical challenges:

- Deconstructability Assessment: Akinade et al. (2015) establish the BIM-based Deconstructability Assessment Score (BIM-DAS) to quantify the recovery potential based on material attributes. O'Grady et al. (2021) expand this scope with the 3DR method (Design for Disassembly, Deconstruction, and Resilience). However, it remains limited to design intent, lacking mandatory post-construction verification. Addressing this gap, Daly (2025) introduces the STaMPD framework, which uniquely integrates a 'physical audit' to validate theoretical scores. Unlike purely predictive models, this approach requires physical disassembly, thereby exposing practical constraints—such as tool accessibility and material degradation—often overlooked in the design phase.
- Digital Tracking: Heesom et al. (2021) propose utilising BIM to track and identify building elements via digital barcodes for safe relocation. Similarly, Hei et al. (2024) also utilise BIM visualisation and QR codes to manage the relocation of a prefabricated house, demonstrating that logistics planning alone significantly reduces waste and emissions.
- Cost Estimation: Tatiya et al. (2018) stands out as the only study to incorporate AI, developing a deconstruction cost estimation model based on case-based reasoning. This approach addresses a financial uncertainty challenge by replacing traditional demolition-based estimates with precise disassembly data.
- Disassembly Sequencing: Sanchez et al. (2019) advance the field by establishing a semi-automated deconstruction programming framework. Employing a heuristic recursive algorithm within a 6D BIM environment, they generate multi-objective selective disassembly plans that synchronise removal paths with project management constraints. This approach allows practitioners to optimise for specific target components, effectively balancing environmental recovery targets against labour costs and scheduling requirements.

3.3.3.1.3. Practical Applications and Evaluation of DfD

Beyond the innovative aspects of DfD, 11 studies focus on evaluating the practical application of DfD strategies and 6 of them focus on existing projects (Jaillon and Poon 2010; Lehmann 2013; Maye Yehia et al. 2024; Montalbano and Santi 2023; Piccardo and Hughes 2022; Priavolou 2018), whereas hybrid and digital models receive limited attention in this category (Hei et al. 2024; Kosman et al. 2018; TM O'Grady et al. 2021). These evaluations offer critical recommendations on four key areas: wood-based material selection, the integration of digital technologies for open-construction systems, the efficacy of digital fabrication methods, and the reusability of components through reversible connections.

In terms of reusable component, Torres et al. (2025) dismantle standard timber-framed walls, reconfirming the established constraint that irreversible fasteners, such as pneumatic nails, compromise component integrity and prevent reuse. Furthermore, Piccardo and Hughes (2022) provide a critical comparative analysis of timber systems by examining multiple existing DfD buildings. Based on their findings, the B.R.I.C. constructed with lightweight timber frames reports no material losses during the disassembly process, validating the efficacy of dry connections. In contrast, projects utilising solid wood or CLT, such as the Ivalsa Modular House, demonstrates minor material losses due to the modifications required to adapt salvaged panels. This suggests that while mass timber offers structural benefits—as highlighted by Lehmann (2013) for high-rise contexts—its monolithic nature may complicate damage-free recovery compared to lightweight framing.

Furthermore, the evaluations often neglect non-structural layers which are crucial for home renovations. O'Grady et al. (2021) stands out as an exception, extending their evaluation beyond the skeleton to include floor coverings, linings, and windows. This comprehensive approach contrasts with other studies such as Kosman et al., (2018), Montalbano and Santi (2023), which focus their evaluations exclusively on the disassembly of the primary structural frame rather than the interior finishes.

Beyond these component-focused analyses, another key identification of the review concerns 'Design Global, Manufacture Local' (DGML) systems, which highlight a shift towards democratised construction. This approach refers to a decentralised model where architectural designs are shared digitally as open-source files but fabricated locally using regionally available materials and tools. Priavolou (2018) examines the WikiHouse system, demonstrating that digital fabrication allows for high-precision connections that lower the barrier to entry for non-experts. Similar strategies are observed in other market-ready systems such as Sim[PLY] (Albright et al. 2017), and X-Frame (Finch et al. 2021). These studies collectively confirm that simplified, easy assembly logic significantly enhances constructability for self-builders. However, despite this, only five studies in the entire review (Montalbano and Santi 2023; Nathansohn et al. 2020; Priavolou 2018; Scuderi 2019; Wilton and Howland 2020) explicitly investigate the intersection of DfD and the self-build housing.

3.3.3.1.4. Environmental Impact and Assessment Tools

The second most investigated area is environmental impact and assessment tools, comprising 28 case studies. These studies focus on quantifying the benefits of DfD, predominantly utilising Life Cycle Assessment (LCA) to measure resource depletion, embodied energy, and CO_2 emissions.

Regarding the specific software employed for these assessments, the review identifies a focused application of BIM-integrated LCA plugins. 'Tally' is mentioned in two studies (De Wolf et al. 2017; Sanchez et al. 2019) to embed environmental data directly into Revit models, facilitating real-time decision-making during the design phase. Additionally, the use of One Click LCA is noted in a single study by Kręt-Grześkowiak and Baborska-Narożny (2023), highlighting its application for automated environmental reporting. Beyond these design-integrated plugins, platforms such as Madaster are highlighted in 2 studies (Çetin et al. 2021; Sun et al. 2022) for their ability to generate 'Material Passports' and circularity indices based on Ellen MacArthur Foundation principles. Madaster monitors material commodity prices in real time, allowing building owners to estimate the value of individual building components and anticipate how these values may change over time (Heisel et al. 2025).

Despite the availability of these tools, the review highlights a critical lack of consensus on circularity assessment frameworks. For example, (Kirchherr et al. 2017) identify 114 different CE definitions. In addition, as noted by Finch et al. (2021), the literature contains over 74 unique assessment tools, leading to fragmented and often incomparable results. This inconsistency arises because circularity frameworks are inherently tied to specific local contexts, transportation distances, and economic variables (Lausselet et al. 2023). Consequently, there is no standardised method for evaluating DfD, making it difficult for practitioners to benchmark the performance of one residential system against another. To address these limitations, Vasquez Cabrera et al. (2025) introduced the CARES framework. This model expands the traditional Material Circularity Indicator by explicitly including maintenance, functional lifespan, and transport logistics. However, the implementation of this expanded scope requires specific regional data and high-fidelity inputs. Taking a different approach, Khadim et al. (2025) state that high circularity does not automatically guarantee sustainability. Using the Whole Building Circularity Indicator (WBCI) LCA framework, their research shows that optimising purely for material recovery can actually increase other environmental burdens depending on the eventual end of life scenarios. This proves that circular strategies must be evaluated alongside their broader environmental consequences rather than in isolation.

A significant finding regarding LCA methodology is the discrepancy between the 'construction' and EoL phases. While the construction stage is based on immediate, measurable data, the EoL phase relies heavily on scenario-based modelling (e.g., Braakman et al. 2021; Claes et al. 2024; Rasmussen et al. 2020). Because the actual disassembly of a building occurs decades in the future, researchers must rely on hypothetical scenarios—predicting future recycling technologies, transport costs, and market demand—rather than empirical data. Similarly, Davis et al. (2025) demonstrate that variations in lifespan assumptions—specifically whether maintenance is modelled by component or by layer—can yield carbon discrepancies that exceed a building's entire initial construction emissions. Kręt-Grześkowiak and Baborska-Narożny (2023) highlight that this reliance on variable human factors and long-term projections introduces significant uncertainty into LCA results.

Parallel to environmental assessment, studies applying Life Cycle Costing (LCC) reveal a distinct economic barrier. While DfD offers potential long-term savings through material recovery, Braakman et al. (2021) demonstrate that the high upfront costs of reversible systems are rarely offset by the relatively small improvement in circularity when measured by current economic models. Furthermore, Gluch and Baumann (2004) argue that converting environmental value into monetary terms often oversimplifies the benefits of DfD.

4. DISCUSSION

4.1. GEOGRAPHICAL DISPARITIES AND POLICY DRIVERS

The dominance of European CE studies likely correlates with the EU's aggressive Circular Economy Action Plan (2020) (see Figure 4). The prominence of Italian studies aligns with the country's implementation of mandatory minimum environmental criteria for public construction, which drives research into material recovery and circularity (Alhawamdeh et al. 2024). This geographical distribution indicates that regulatory pressure actively shapes both the academic focus and the practical adoption of circular design strategies.

4.2. UNDEREXPLORED RESIDENTIAL SCOPES

The critical synthesis of 71 case studies reveals that while DfD research frequently utilises residential buildings as test subjects, it often fails to engage with the specific socio-technical reality of housing. This disconnection manifests in 7 primary thematic areas:

4.2.1. BUILDING SCALE AND TYPOLOGY

Studies are concentrated in Europe due to frameworks like the EU Green Deal (2019) and Circular Economy Action Plan (2020), resulting in a low-rise focus. Furthermore, the broad categorisation obscures critical typological distinctions; for instance, only Friedman (2025a) explicitly differentiates between detached and row houses.

Currently, 66% of case studies focus on low-rise buildings, likely due to easier prototyping, leaving mid- and high-rise sectors underrepresented. However, this low-rise focus limits the transferability of current research to high-density urban environments, which represent the primary trajectory of global urbanisation (UN-Habitat 2022). While isolated European pilot projects such as Architekten Cie's 'Circl' building in Amsterdam, Building D(emountable) and Superlocal, Super Circular Estate project (Graaf et al. 2022) in Limburg present opportunities for further research into larger-scale applications, the lack of empirical high-rise research represents a critical barrier, suggesting that the industry has not yet resolved the "wet trade" problem in dense urban housing.

Furthermore, existing studies frequently treat the building in isolation, overlooking critical site constraints. As noted by Balogun et al. (2024), the feasibility of deconstruction is governed not only by logistical factors like accessibility and infrastructure but also by social constraints, where community resistance regarding historical or sentimental value can significantly impede DfD projects.

Methodological analysis across these scales demonstrates a distinct trajectory away from purely theoretical exploration toward applied testing and validation through specific building examples, particularly at the low-rise scale. This distinction is critical to understanding whether current strategies are being tested empirically or merely simulated. The data suggests that while innovative design proposals are being rigorously prototyped for single family housing, high rise applications remain largely theoretical or observational. This lack of empirical physical validation highlights that the application of disassembly principles to mid- and high-rise buildings, where waste generation is highest, remains a critically under explored area.

4.2.2. LACK OF INTEGRATED RESEARCH FOCUS

An analysis of the key research areas reveals a significant lack of integrated research. While design proposals and environmental assessments are both well represented, they largely exist in silos. This highlights a critical gap: innovative designs are rarely validated with rigorous environmental data, and conversely, environmental assessments are often applied to existing built projects rather than novel reversible systems. Furthermore, the relatively low number of studies evaluating practical applications indicates that the discipline remains an experimental field. However, physical evaluations offer essential data that digital simulations often miss. Specifically, they provide direct evidence on actual disassembly times, labour costs, and material degradation.

Finally, the scarcity of deconstruction method proposals suggests that while the industry is focused on designing new reversible buildings, there is a distinct lack of research on how to effectively dismantle them, particularly regarding the operational planning and safety of the deconstruction phase.

4.2.3. ECONOMIC BARRIERS

In terms of the housing industry, the economic feasibility of DfD remains a critical challenge. As Braakman et al. (2021) indicate, the additional costs of specialised detailing and labour often outweigh the discounted value of future material recovery.

This imbalance highlights a fundamental disconnect in the structure of the speculative housing market. Typically, the developer bears the immediate cost of implementing DfD strategies, while the financial benefit of disassembly—reaped decades later—accrues to the future homeowner. Because developers cannot capture this long-term value, there is little economic motivation to invest in reversibility. This suggests that DfD is not merely an engineering challenge, but a business model problem that requires a shift in how housing value is calculated. Consequently, the high initial capital required, combined with the unpredictability of future resale values, remains a primary obstacle to the adoption of DfD in the housing industry.

4.2.4. HOUSING SHORTAGE AND CRISIS RESPONSE

Although flexibility, rapid assembly, and modular construction have been historically linked to addressing housing deficits (Blasco and Fausto 2024), the application of DfD to these challenges remains uneven. Furthermore, regarding the broader permanent housing shortage, the literature is notably sparse; only Ferreira Silva et al. (2020) explicitly identify DfD strategies as a solution.

Although rapid response shelters demonstrate the functional portability of disassembly strategies (Asmat et al. 2022; Pérez-Valcárcel et al. 2024) this alignment between reversibility and disaster relief remains significantly underexplored. This proves that reversible buildings are not solely about waste minimisation; they are about portability and response. However, despite the clear alignment between DfD principles (speed, reversibility, flexibility) and disaster relief, this specific focus remains significantly underexplored, represented by only a fraction of the reviewed cases. Consequently, the application of DfD to crisis scenarios and the housing deficit represents a critical research gap.

4.2.5. SOCIAL DIMENSIONS AND DEMOCRATISATION

DfD is currently treated as a technological puzzle (connections, joints, materials). However, in the residential sector, the user is the primary agent of change. Almost none of the selected studies explore DfD from a social perspective. This means the literature overlooks occupant behaviour and the 'democratisation of construction'—defined as reducing technical barriers to empower non-expert occupants (DIY) to assemble or modify their dwellings. Aligning with Kara et al. (2022), who note that the CE is currently approached primarily as a technological challenge, this review finds that the active participation of the resident receives little attention.

However, the rising cost of construction materials and labour makes DfD an attractive strategy—particularly for self-builders who anticipate future renovations, extensions, or even complete deconstruction. Although very few people actually carry out the building process themselves (Scuderi 2019), client involvement in the design stage remains critical and has the potential to revolutionize the sector (Roxas et al. 2023).

Consequently, the practical application of DfD by non-professionals remains largely unexamined. The literature focus on expert led technological solutions limits the democratisation of circular housing, effectively ignoring the self-build sector potential.

4.2.6. MISALIGNMENT OF GOALS (WASTE VS. ADAPTABILITY)

A recurrent tension in the literature concerns whether DfD in residential buildings is primarily intended to reduce demolition waste at the EoL stage or to support adaptability during the use phase. Most DfD studies emphasise long-term material recovery, framing buildings as "material banks" to be harvested decades in the future (Guerriero et al. 2024; Kirchherr et al. 2017). This aligns with circular economy initiatives such as Buildings as Material Banks (BAMB), which prioritise future reuse and resource retention (Capelle et al. 2019; Çetin et al. 2021).

However, focusing solely on a building's end of life often overlooks how a resident's spatial needs evolve in the short term. Research into building adaptability places a strong emphasis on near term flexibility, where spaces and components can adapt to changing household conditions. The COVID-19 pandemic made this requirement particularly obvious. Djukanovic et al. (2025) note that crises revealed the rigidity of current housing stock, highlighting the critical role of flexibility in accommodating unforeseen lifestyle shifts.

Similarly, Ottenhaus et al. (2023) demonstrate how design for adaptability (DfA) can support ongoing reconfiguration during use while still enabling future disassembly and material recovery. Friedman (2025b) also emphasises the importance of adaptability in extending a home's lifespan, thereby prolonging its life cycle and reinforcing CE principles. Integrating adaptability with DfD can therefore extend a building's service life and reduce premature demolition (Pomponi and Moncaster, 2017), yet only a minority of studies address both aims concurrently.

Consequently, this highlights a major gap in current DfD research. Studies focus almost entirely on EoL recovery and overlook everyday adaptability in residential settings.

4.2.7. RESEARCH ON EMERGING TECHNOLOGIES

While digital tools are increasingly integrated into circular workflows, the review identifies a functional gap between Assessment and Planning. Current industry standard assessment frameworks, such as Tally, One Click LCA, and Madaster, function primarily as retrospective accounting mechanisms rather than predictive design aids. By strictly quantifying carbon or cataloguing materials after a design is fixed, these tools fail to mitigate the uncertainty of future disassembly. Specifically, static LCA models rely on hypothetical EoL scenarios, failing to account for the physical degradation or market variability that will occur over a building's 50-year lifespan.

The application of AI in this domain remains nascent. Apart from Tatiya et al. (2018), who utilise Case-Based Reasoning to address the financial uncertainty of deconstruction cost estimation, the specific use of AI to solve residential DfD challenges remains largely unexamined. While studies by Oluleye et al. (2023) and Çetin et al. (2021) have comprehensively mapped AI applications for waste management, reverse logistics, and material life cycle optimisation, the intersection of AI with the architectural design of reversible connections and the social nuances of user-led disassembly remains underexplored. However, this integration requires critical oversight; as Kaack et al. (2022) caution, the deployment of large-scale AI models must be evaluated against their operational carbon footprint, ensuring that the computational energy demand does not undermine the net environmental gains of the circular strategy.

4.3. FUTURE RECOMMENDATIONS

4.3.1. ADVANCING HIGH-RISE TYPOLOGIES

To advance the field and address the critical scarcity of studies at denser scales, future research must prioritise the mid- and high-rise sectors by moving beyond theoretical modelling to investigate complex site logistics and social acceptance. Crucially, designing modular systems specifically capable of functioning in multi storey environments would significantly advance the field. Without validating disassembly principles in high density scenarios, the industry cannot realistically meet global waste reduction targets or address the rapid housing demand in urbanising regions, where vertical densification is the primary strategy for accommodating growth.

4.3.2. ECONOMIC AND POLICY INTERVENTIONS

The housing industry may need to move toward alternative ownership models or new mortgage products that recognise the residual value of the building as a material bank, thereby incentivising owners to maintain the assets reversibility. Until financial institutions formally recognise these residual material values to offset initial construction risks, the economics of residential circularity will likely remain difficult to justify in a traditional linear market. Alongside economic shifts, policy must adapt. Future studies must link reversibility with emergency response logistics to foster climate resilience. Crucially, mandating disassembly principles in public procurement would transform temporary shelters into recoverable material banks, aligning humanitarian interventions with circular economy targets.

4.3.3. ARTIFICIAL INTELLIGENCE AND DIGITAL PATHWAYS

Recent advancements demonstrate that AI could address the specific gaps identified in this review—namely, LCA uncertainty, the optimisation and automation of deconstruction sequencing, digital twins for disassembly analysis, and large language models as technical guides:

4.3.3.1. PREDICTIVE CIRCULARITY MODELLING (MACHINE LEARNING)

Addressing the uncertainty inherent in environmental assessment, current research often relies on deterministic EoL scenarios that assume idealised future conditions—such as specific recycling technologies or market values—which fail to account for the unpredictable reality of a building's fifty-year lifespan. This suggests that the "circularity potential" calculated by current tools is often a theoretical projection rather than a guaranteed outcome, dependent on future systemic conditions that architects cannot control.

For example, if an LCA assumes a 90% recycling rate for a timber beam in 50 years, but the market for recycled timber collapses, or if the glue used in lamination renders it toxic by 2070 standards, the LCA is invalid.

To mitigate this limitation, Rakhshan et al. (2021) propose the use of Supervised Machine Learning (ML) algorithms as a robust alternative to static assessment tools. Unlike standard methods that rely on fixed recycling rates, their probabilistic model predicts the reuse potential of structural elements by analysing dynamic data on material degradation and market demand. This approach can effectively move DfD evaluation from hypothetical 'best-case scenarios' to data-driven probability, ensuring that circularity claims remain resilient against future uncertainty. Therefore, uncertainty in LCA should not be seen merely as a limitation, but as a central challenge—one that AI and probabilistic modelling are uniquely equipped to address.

4.3.3.2. AUTOMATED DISASSEMBLY SEQUENCING (RL)

Deconstruction is a complex process that requires the simultaneous management of interdependent structural sequences, hazardous material identification, and dynamic site logistics to prevent premature collapse or injury. In the manufacturing sector, Reinforcement Learning (RL) agents have been trained to learn optimal disassembly sequences for complex assemblies (Allagui et al. 2023). Applying these RL agents to the built environment would allow for the simulation of thousands of removal scenarios, identifying optimal dismantling paths that minimise safety risks in high-rise contexts.

4.3.3.3. MATERIAL RECOGNITION FOR EXISTING STOCK (COMPUTER VISION)

Addressing the renovation of existing stock, Computer Vision offers a pathway to digitise older buildings. Most DfD strategies focus on new builds, often neglecting the existing stock due to the lack of accessible data regarding its material composition and structural connections. However, recent developments in adjacent fields have enabled the automated classification of construction waste from site images (Lu et al. 2022). Future DfD research could deploy similar algorithms via drones to automatically classify materials and connection types in older residential buildings. This technology serves as the critical enabler for retroactive Material Banking, allowing the vast volume of existing housing stock to be digitised and catalogued despite the absence of original design data.

Crucially, by quantifying the residual value of these identified components, this digital framework makes the long-term financial advantages of circularity transparent to both current and future occupants. Prospective buyers can evaluate the harvestable reuse value of a home prior to purchase, allowing this component data to be formally integrated into alternative mortgage models. In this way, computer vision not only resolves a technical data gap but provides the necessary foundation to address the economic barriers of circular housing.

4.3.3.4. FACILITATING KNOWLEDGE TRANSFER (LLMS)

Addressing the social dimension, Large Language Models (LLMs) offer a pathway to support the self-build sector. Future studies must therefore bridge this gap by developing 'user-centric' disassembly protocols that simplify technical connections for the non-expert self-builders, ensuring that circularity remains viable even without professional maintenance.

Emerging research demonstrates the capability of LLMs to interpret and translate complex building regulations into accessible rules (Fuchs et al. 2024). By training LLMs on design rules and technical disassembly manuals, researchers can develop "Intelligent Assistants" that guide non-expert self-builders through design decisions, renovation processes, translating complex engineering data into simple, step-by-step vernacular instructions.

4.4. LIMITATIONS

This systematic review is subject to certain limitations regarding scope and methodology. Firstly, the primary systematic database search was restricted to English-language peer-reviewed journal articles published between 2010 and 2025. However, a limitation remains that a systematic search of all grey literature was not conducted, potentially excluding other emerging prototypes not yet documented in peer-reviewed outlets.

Secondly, the search strategy prioritised DfD and residential terminology over computational keywords (e.g., 'Large Language Models' or 'Computer Vision'). Consequently, this review captures technological applications only where they explicitly intersect with the established DfD discourse. While this approach effectively maps the current state of integrated research, it may exclude isolated computational experiments published in niche computer science journals that have not yet bridged the gap to architectural literature.

Finally, the classification of case studies involved a degree of interpretation, particularly when distinguishing between 'Digital', 'Hybrid' or ‘Primary Focus’, ‘Adaptable to Residential’ validation methods in studies with ambiguous methodologies. While a structured protocol and independent cross checking were applied during the methodology to mitigate this subjectivity, some level of interpretive bias cannot be entirely eliminated. To ensure full transparency and reproducibility, the complete categorisation dataset is provided as supplementary material.

5. CONCLUSION

This systematic review advances the discourse on Design for Disassembly in the residential sector by synthesising evidence from 95 peer-reviewed articles and 71 case studies to expose critical misalignments between current theoretical frameworks and the practical realities of housing. A primary scientific novelty of this study is the identification of a significant validation gap across building scales. The analysis demonstrates that while low-rise residential systems benefit from rigorous hybrid, physical and digital prototyping, research into mid- and high-rise scales relies almost entirely on digital simulations, leaving the physical complexities of dry assembly in high-density environments unresolved.

Furthermore, the review contributes a critical assessment of methodological silos, revealing that architectural design innovations are rarely integrated with environmental assessments, and that current Life Cycle Assessment tools suffer from uncertainty due to their reliance on static, long-term end-of-life prediction scenarios. The study also highlights that current literature predominantly treats circularity as a purely technical challenge, critically overlooking the social democratisation of construction and the economic necessity of new ownership models that capture long-term material value.

To advance the field and achieve a scalable circular transition, future research would benefit from shifting from isolated low-rise inventions towards the systemic integration of multi-storey typologies. Researchers and policymakers should seek to move beyond theoretical simulations to physically validate reversible connections in dense urban settings, specifically targeting the elimination of wet trades. Furthermore, to ensure the economic viability of these strategies, this review recommends the development of alternative mortgage products and business models that formally recognise the residual value of homes as material banks.

Finally, accelerating this transition can be supported by the strategic application of emerging digital technologies to solve the specific operational gaps identified in this review. The field could leverage machine learning to transition from static environmental accounting to predictive circularity modelling, mitigating the uncertainty of future material degradation and market fluctuations. Additionally, computer vision offers a pathway to digitise the existing housing stock for retroactive material banking, while reinforcement learning has the potential to optimise complex disassembly sequencing. To address the social dimension, large language models could be utilized to translate complex engineering constraints into accessible guidelines, empowering non-expert occupants to actively participate in the construction and deconstruction of their homes.

Supplementary files

Supplementary file 1: Codebook - Supporting Material. Coded themes from NVivo Software.
Supplementary file 2: Supplementary Data. Categorisation of analysed articles.

AUTHOR CONTRIBUTIONS

Cem Cetin: Conceptualisation, Literature Review, Data Curation: Developed the overarching themes and objectives of the review. Methodology: Designed the review framework and criteria for literature selection. Writing – Original Draft: Wrote the initial manuscript draft, including key sections. **Nils Jaeger**: Writing – Review & Editing: Assisted in editing and refining the final manuscript, ensuring accuracy and completeness. Supervision – Supervised the study. All authors have read and approved the final version of the manuscript.

COMPETING INTERESTS

The author(s) has/have no competing interests to declare.

DATA ACCESSIBILITY

The datasets generated and analysed during the current study are available and accessible as supplementary files.

ETHICAL APPROVAL

During the preparation of this work the author(s) used ChatGPT in order to improve the grammatical accuracy and readability of the manuscript. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the published article.

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