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SYSTEMATIC REVIEW OF MANUAL AND EQUIPMENT-BASED DEMOLITION TECHNIQUES FOR LOW-RISE BUILDINGS

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Abstrak

Bangunan bertingkat rendah, yang secara umum didefinisikan sebagai bangunan dengan satu hingga empat lantai, merupakan tipologi bangunan hunian dan komersial skala kecil yang paling dominan di banyak negara, khususnya di kawasan Asia Tenggara, Afrika Sub-Sahara, Amerika Latin, serta sebagian wilayah Timur Tengah. Pembongkaran bangunan-bangunan tersebut—baik dalam konteks regenerasi perkotaan, pembersihan pascabencana, maupun pembangunan kembali oleh pemilik individu—dilaksanakan melalui beragam metode yang mencakup pekerjaan manual sepenuhnya menggunakan alat tangan hingga proses mekanis berbasis ekskavator. Kajian sistematis ini menelaah secara komprehensif teknik-teknik pembongkaran manual dan berbasis peralatan utama yang diterapkan pada bangunan bertingkat rendah, dengan menganalisis setiap pendekatan dari segi karakteristik teknis, kebutuhan operasional, implikasi keselamatan, potensi pemulihan material, dan kinerja ekonomi. Faktor-faktor yang menentukan pemilihan metode—meliputi tipologi struktur, keterbatasan akses lokasi, kedekatan dengan bangunan sekitar, anggaran proyek, dan keberadaan material berbahaya—juga dikaji secara kritis. Dua tabel ringkasan terstruktur disajikan: gambaran kinerja komparatif dan matriks pengambilan keputusan multi-kriteria sebagai panduan pemilihan metode dalam praktik. Kajian menyimpulkan bahwa tidak ada satu teknik pembongkaran yang secara universal paling optimal; pendekatan yang paling sesuai ditentukan oleh kombinasi faktor spesifik lokasi, teknis, ekonomi, dan regulasi. Kesenjangan pengetahuan utama diidentifikasi, dengan penekanan khusus pada konteks negara berkembang di mana pembongkaran bangunan bertingkat rendah paling banyak dilakukan namun masih minim regulasi formal.

Kata kunci— *pembongkaran bangunan bertingkat rendah, pembongkaran manual, pembongkaran mekanis, dekonstruksi selektif, pemilihan metode pembongkaran*

Abstract

Low-rise buildings, broadly defined as structures of one to four storeys, represent the dominant residential and small commercial building typology in many countries, particularly across Southeast Asia, Sub-Saharan Africa, Latin America, and parts of the Middle East. Their demolition—whether for urban regeneration, post-disaster clearance, or individual redevelopment—spans a wide spectrum of approaches, from entirely manual hand-tool operations to fully mechanised excavator-based processes. This systematic review comprehensively examines the principal manual and equipment-based demolition techniques applicable to low-rise buildings, analysing each in terms of technical characteristics, operational requirements, safety implications, material recovery potential, and economic performance. The factors governing method selection—including structural typology, site access constraints, proximity to adjacent structures, project budget, and the presence of hazardous materials—are also critically examined. Two structured summary tables are presented: a comparative performance overview and a multi-criteria decision matrix to guide method selection in practice. The review concludes that no single demolition technique is universally optimal; the most appropriate approach is determined by a combination of site-specific, technical, economic, and regulatory factors. Key knowledge gaps are identified, with particular emphasis on developing-country contexts where low-rise demolition is most prevalent yet least formally regulated.

Keywords— *low-rise building demolition, manual demolition, mechanical demolition, selective deconstruction, demolition method selection*

1. INTRODUCTION

Among the many activities constituting the construction lifecycle, building demolition stands out as one of the most physically intensive and technically underspecified domains. While substantial scholarly attention has been directed towards large-scale demolition—including high-rise towers, industrial facilities, and bridges—the systematic dismantling of low-rise buildings has received comparatively limited treatment in the engineering literature. This gap is significant, given that low-rise buildings constitute the dominant typology in most national building stocks and are the structures most frequently subject to demolition across urban and rural settings [1][2].

For the purposes of this review, the term low-rise building refers to structures of one to four storeys, encompassing detached and semi-detached houses, terraced dwellings, low-rise apartment blocks, shophouses, small commercial premises, schools, and community buildings. These structures exhibit considerable diversity in material composition and construction method, including load-bearing masonry, timber-framed systems, reinforced concrete frames with masonry infill, and various combinations thereof. The structural form and material composition are among the most influential determinants of which demolition method is technically appropriate [3][4].

Demolition of low-rise buildings is undertaken by an extraordinarily diverse range of operators. In developed countries, established demolition contractors deploy sophisticated mechanical equipment and operate within formal regulatory frameworks. In developing countries, however, demolition is frequently conducted by informal labour gangs using hand tools with minimal supervision and no systematic waste management [2][5]. The consequences include elevated occupational injury rates, avoidable losses of recoverable materials, and uncontrolled release of hazardous substances.

From a technical perspective, the choice between manual and equipment-based demolition involves fundamental trade-offs. Manual methods offer precision and material selectivity at the cost of low productivity. Equipment-based approaches using hydraulic excavators are considerably faster but generate mixed waste and impose demanding site access requirements. Between these poles lie intermediate options—mini-excavators, skid-steer loaders, and robotic plant—whose suitability depends on site-specific constraints [6][7].

A critical examination of the existing literature reveals a specific and consequential knowledge gap that motivates the present review. Although the technical characteristics of individual demolition methods—including hydraulic excavation, pneumatic breaking, and selective deconstruction—have each been documented in published studies, no prior work has systematically compared these methods across the full range of performance dimensions simultaneously relevant to low-rise building demolition: technical suitability, safety risk profile, material recovery potential, economic performance, and site constraint compatibility. This fragmentation means that practitioners seeking guidance must assemble their own comparative assessment from heterogeneous and inconsistently scoped sources. A further dimension of the gap is geographical: the overwhelming majority of existing demolition research originates from European, North American, Australian, and Chinese contexts, characterised by formal regulatory oversight, modern mechanical plant, and established waste management infrastructure. The conditions prevailing across Southeast Asia, Sub-Saharan Africa, and Latin America—where low-rise informal buildings constitute the majority of structures subject to demolition, but formal regulatory frameworks are weak or absent—are substantially underrepresented in the literature. This disparity between the geographic distribution of demolition activity and the geographic distribution of demolition research constitutes a central knowledge deficit that the present review is designed to address.

This article reviews the principal manual and equipment-based demolition methods as applied to low-rise buildings, drawing on peer-reviewed literature, technical standards, and case study evidence from multiple national contexts. The specific objectives are: (1) to describe the technical characteristics and operational requirements of each principal demolition method; (2) to examine the safety, environmental, and economic dimensions of each method; (3) to identify the factors governing method selection; (4) to present comparative summaries of method performance; and (5) to identify areas where further research is urgently required.

The principal novelty of this review resides in the systematic and simultaneous integration of technical performance, occupational safety, material recovery, and economic dimensions across all principal demolition methods specifically scoped to one-to-four-storey buildings—a synthesis not previously available in the peer-reviewed literature. Prior systematic reviews have addressed construction and demolition waste management at a general building stock level, or have evaluated specific techniques such as selective deconstruction or hydraulic excavation in isolation; none has mapped the full spectrum of demolition methods against a unified multi-criteria decision framework calibrated for low-rise typologies. The two structured summary instruments presented in Section 3.8—a comparative performance overview and a multi-criteria decision matrix—constitute directly deployable decision-support tools applicable by demolition contractors, structural engineers, municipal authorities, and building owners. Their utility is particularly pronounced in developing-country contexts, where formal method selection guidance is absent and practitioners currently rely on informal convention rather than systematic technical assessment. By consolidating evidence from diverse national settings into a single accessible reference, this review contributes both to the theoretical organisation of demolition engineering knowledge and to the practical improvement of decision-making in a domain with significant safety, environmental, and economic consequences.

2. METHODS

2.1 Search Strategy and Database Selection

This study is conducted as a systematic literature review conforming to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework [8]. Literature searches were conducted across three electronic databases: Scopus, Web of Science, and Google Scholar. The search was structured using Boolean operators combining primary terms—'building demolition,' 'structural demolition'—with secondary terms including 'low-rise,' 'manual demolition,' 'mechanical demolition,' 'selective deconstruction,' 'construction and demolition waste,' 'demolition safety,' and 'demolition method selection.' The search was restricted to publications issued between 2014 and 2024; seminal or foundational works predating this window were selectively included where their theoretical or technical contribution remained unreplaced. All searches were conducted in the English language. Grey literature—including national technical standards, regulatory guidelines, and institutional reports from bodies such as ASTM International, ISO, and national health and safety agencies—was incorporated where it provided technical context not available in peer-reviewed sources.

2.2 Inclusion and Exclusion Criteria

Publications were included in the review if they satisfied all of the following criteria: (1) direct technical relevance to demolition methods applicable to low-rise or residential-scale buildings (one to four storeys); (2) substantive engagement with at least one of the following outcome dimensions: technical performance, occupational safety, material recovery and recycling, or economic assessment; and (3) publication as a peer-reviewed journal article, standard, or official institutional report. Studies were excluded if they addressed exclusively large-scale demolition contexts—such as high-rise towers, bridges, or industrial plant—without transferable implications for low-rise practice, or if they addressed construction activity without specific reference to demolition or deconstruction processes. Conference papers were included only where equivalent findings had not been published in journal form.

2.3 PRISMA Literature Search Flow

Database searches initially returned 214 records (Scopus: 98; Web of Science: 67; Google Scholar: 49). Following removal of duplicate records (n = 41), a total of 173 unique records were screened at the title and abstract level, of which 108 were excluded as not meeting the low-rise demolition scope criteria. Full-text review was conducted for 65 records; 38 were subsequently excluded (29 for insufficient technical specificity to demolition methods; 7 for exclusive high-rise or infrastructure scope; 2 for inability to retrieve full text). A total of 27 peer-reviewed articles and official reports were included in the final synthesis, supplemented by 4 national technical standards.

2.4 Data Extraction and Thematic Analysis

Data extraction was performed using a standardised template recording the following fields for each included study: authors, publication year, country or regional context, study design (experimental, case study, computational modelling, or review), demolition method(s) addressed, building typology, key quantitative findings, and reported limitations. Extracted data were organised in a structured spreadsheet to facilitate systematic cross-study comparison and thematic grouping.

Thematic synthesis was employed as the primary analytical method for integrating the extracted qualitative and quantitative evidence. The synthesis followed a six-stage procedure adapted from Braun and Clarke (2006) [9]: (1) familiarisation with the full body of extracted data; (2) generation of initial codes corresponding to technical attributes, safety outcomes, and performance metrics reported across source studies; (3) grouping of related codes into candidate themes; (4) review and refinement of themes against the full dataset; (5) definition and naming of final themes; and (6) production of the narrative synthesis. Five principal themes were identified through this process: (i) structural typology and method suitability; (ii) manual demolition methods and occupational health; (iii) equipment-based methods and site constraints; (iv) selective deconstruction and material recovery economics; and (v) factors governing method selection governance. These themes are reflected directly in the section structure of the Results and Discussion.

3. RESULTS AND DISCUSSION

3.1 Low-Rise Building Typologies and Their Implications for Demolition

The structural typology of a low-rise building exerts direct and decisive influence on demolition method selection. Four broad categories are most relevant to demolition practice: load-bearing masonry, timber-framed construction, reinforced concrete (RC) frame with masonry infill, and plain or unreinforced concrete.

Load-bearing masonry buildings are the most prevalent typology in low-rise stocks worldwide. Structures built before the mid-twentieth century were typically constructed with lime mortar, which is considerably softer than modern cement mortar. Lime-mortared masonry is generally more amenable to hand tool demolition and brick recovery than cement-mortared masonry, where units tend to fracture during removal [10][11]. Ring beams, concrete lintels, and embedded steel ties complicate manual removal and frequently necessitate power tools or small mechanical plant.

Timber-framed buildings are generally the most amenable to manual and selective demolition. The principal structural elements are typically fastened with nails, bolts, or traditional joinery connections that can be released without destroying the members themselves, making these buildings particularly suitable for selective deconstruction [12]. However, older timber buildings may contain lead paint, chromium or arsenic preservative treatments, or asbestos-reinforced roofing and cladding materials requiring careful management [13].

RC frame structures with masonry infill are prevalent in low-rise commercial and residential buildings throughout Asia, the Middle East, and Latin America. Breaking a reinforced concrete element requires fracturing the concrete matrix and cutting the embedded steel reinforcement bars, necessitating mechanical cutting tools or oxyacetylene or plasma cutting equipment [2][14]. The proportion of RC framing to masonry infill is therefore a key determinant of the extent to which mechanical plant is required.

Unreinforced or plain concrete structures, including mass concrete foundations and ground-bearing slabs, represent an intermediate case. Although harder and more resistant to impact than masonry, they lack the tensile ductility conferred by reinforcement. Demolition typically requires pneumatic or hydraulic breakers and produces homogeneous concrete rubble suitable for crushing and recycling as aggregate [15][16].

3. 2 Manual Demolition Methods

Hand tool demolition is the oldest and most universally practised form of building removal. It involves the systematic application of percussion tools—sledgehammers, club hammers, cold chisels, and masonry chisels—combined with levering tools such as crowbars and wrecking bars. It remains widely employed where mechanical plant is unavailable or unaffordable, where site access is severely restricted, or where selective material recovery is the primary objective.

The conventional top-down demolition sequence proceeds from roof coverings, through the roof structure, ceiling materials, floor boards and joists, to the structural walls. This sequence is essential for maintaining structural stability; premature removal of wall sections below floor or roof level can precipitate uncontrolled collapse [3][17]. Maintaining the correct sequence demands supervisory oversight and operatives who understand the structural system being demolished—a requirement frequently unmet in informal settings.

The principal advantage of hand tool demolition is precision and selectivity: individual materials can be separated and components recovered intact. The primary disadvantage is very low productivity. A masonry wall that a mechanical excavator clears in minutes may require several hours of skilled hand tool work. In commercial demolition, productivity limitations generally confine hand tools to specific precision tasks, such as opening party walls or working adjacent to retained structures [1][6].

Pneumatic and hydraulic power tools represent a substantial productivity step up while retaining positional flexibility. The pneumatic breaker or jackhammer—available from lightweight 3–5 kg chipping hammers to heavy 30–40 kg paving breakers—delivers high-frequency percussive blows to fracture concrete and masonry progressively. Electric rotary hammer drills and cordless demolition hammers have increasingly supplanted pneumatic tools due to the elimination of the compressor and air hose, lower noise levels, and reduced vibration transmission [18][19].

A significant occupational health concern associated with sustained use of power tools is hand-arm vibration syndrome (HAVS), a vascular and neurological condition caused by prolonged vibration exposure. HAVS produces vibration-induced blanching of the fingers, loss of grip strength, and peripheral numbness, and is irreversible once established. Regulatory limits on daily vibration exposure—expressed as an eight-hour energy-equivalent acceleration value A(8)—are specified in standards including the EU Physical Agents Directive and equivalent national regulations [20][21].

Effective manual demolition also requires a clearly defined and competently supervised sequence. Load-bearing elements must not be removed before the loads they carry have been redistributed or temporarily supported, and structural stability must be maintained throughout. This requires the demolition supervisor to possess knowledge of structural behaviour, including how load paths change as elements are progressively removed, and the capacity to adapt when unexpected conditions—concealed reinforcement, informal prior modifications, or structural deterioration—are encountered [3][22].

3. 3 Equipment-Based Demolition Methods

The hydraulic excavator fitted with a hydraulic breaker is the most widely deployed mechanical plant in low-rise building demolition across developed and many developing countries. In low-rise demolition, medium-sized breakers of 200 to 800 kg, typically mounted on 5 to 20-tonne excavators, are most commonly deployed. The breaker delivers high-energy percussive blows through a hydraulically driven piston, progressively fracturing the substrate. In masonry demolition, the excavator bucket or demolition shear is subsequently used to remove the resulting rubble [14][23].

A key consideration in urban low-rise demolition is the physical footprint of the plant. A 15-tonne excavator requires a working width of at least 4 to 6 metres and imposes ground pressures that may be problematic on weak ground, over basements, or adjacent to shallow foundations. In constrained urban plots—narrow alleys characteristic of historic city centres and informal settlements—conventional excavators may be entirely impractical [24][20].

Where demolition involves significant reinforced concrete, the hydraulic pulveriser or concrete crusher attachment offers advantages over the standard breaker. These attachments grip and crush concrete elements, simultaneously separating debris from embedded steel reinforcement. The liberated reinforcement is recovered as ferrous scrap, while the concrete is processed on site or transported off site for use as recycled concrete aggregate (RCA) [15][16]. Pulveriser attachments typically generate less vibration and noise than hydraulic breaking, an advantage in occupied residential settings.

The mini-excavator, generally defined as a tracked or wheeled excavator with an operating weight of six tonnes or less, is particularly valuable where site access is restricted. Machine widths of 1.5 to 2.0 metres allow operation in sites inaccessible to conventional plant, including through standard doorways and within building footprints. Mini-excavators are commonly deployed for internal demolition of partition walls and floor slabs, and for shallow foundation excavation [25][7]. The use of mini-excavators for internal demolition raises specific structural safety considerations, as existing floor slabs must be confirmed capable of supporting the machine before access is permitted [17][26].

The skid-steer loader and telescopic handler serve primarily material-handling and loading functions rather than primary structural breaking. Their compact dimensions and high manoeuvrability make them useful complementary machines alongside manual or mini-excavator demolition. The telescopic handler adds upward reach capability, potentially reducing the need for scaffolding [6].

The wrecking ball—a large cast-iron or steel sphere suspended from a crane jib—is now rarely employed in low-rise demolition in developed countries, having been largely superseded by hydraulic breaker methods. It remains in occasional use for isolated masonry structures such as chimneys where the surrounding site is clear. The method is unsuitable for confined urban sites due to the unpredictability of impact force direction, potential for large debris to travel considerable distances, and limited controllability at close range [24][7].

3. 4 Selective Deconstruction

Selective deconstruction—also referred to as soft-strip demolition or careful dismantling—occupies a distinct position among demolition methods, with the primary objective of recovering building materials in a condition suitable for reuse or high-quality recycling. The method involves systematic, manual or semi-manual removal of building components in a pre-planned reverse sequence, from finishes and fixtures through to structural elements, with materials sorted and staged for recovery as the work progresses [12][11].

The application of selective deconstruction is most technically feasible and economically viable for timber-framed structures. Research has demonstrated material recovery rates of 70 to 90 percent by mass for well-executed selective deconstruction of timber-framed residential buildings, compared with 20 to 40 percent for conventional mechanical demolition of similar structures [10][27]. However, the productivity of selective deconstruction is substantially lower—typically by a factor of three to five—than conventional demolition for an equivalent volume of material removed.

The economic viability of selective deconstruction depends critically on the values achievable for recovered materials relative to additional labour costs. In markets where reclaimed timber, brick, and architectural features command significant premiums, selective deconstruction can be economically competitive with conventional demolition. Where reclaimed material values are low or secondary markets are underdeveloped, policy interventions—landfill taxes, extended producer responsibility schemes, or minimum material recovery targets—may be required [27][16].

A pre-demolition audit for selective deconstruction requires thorough assessment of the building to identify recoverable components, estimate quantities and quality, and determine the optimal removal sequence. Building information modelling (BIM) tools, adapted for existing buildings through scan-to-BIM workflows, can support this process by providing a threedimensional material inventory against which recovery options can be systematically evaluated [10][22].

3. 5 Factors Governing Demolition Method Selection

The selection of a demolition method for a low-rise building is rarely straightforward. It results from a multi-criteria assessment weighing technical feasibility against economic, regulatory, safety, and logistical considerations.

The structural typology and material composition of the building are the primary technical determinants of method suitability. The condition of the structure—particularly the presence of deterioration, previous modifications, or non-standard construction—is equally important, since structurally weakened elements may behave unpredictably, increasing the risk of uncontrolled collapse [3][4].

Site access and available working space are among the most practically constraining factors. In the narrow plots and tight street patterns of historic urban cores, informal settlements, and dense residential areas, the requirements of full-size hydraulic excavators are frequently unachievable, making manual or mini-excavator methods the only viable options [28][20].

Where the building is immediately adjacent to occupied structures, methods that generate high vibration—heavy hydraulic breaking, wrecking ball impacts—are generally inappropriate. Selective deconstruction or hand tool demolition is typically preferable where the adjacent structure proximity is less than one to two metres [24][7].

The presence of asbestos-containing materials, lead paint, or other hazardous substances mandates a phased approach in which hazardous materials are identified, removed by licensed specialists, and disposed of through certified waste streams before structural demolition commences. Removal and disposal costs can constitute a major component of total project cost [13][5].

Where the project objective includes maximisation of material recovery—driven by regulatory requirements, economic incentives, or client sustainability commitments—methods with higher selectivity are favoured. Conversely, where rapid site clearance is the primary objective, high-productivity mechanical methods are preferred even at the cost of lower recovery rates [15][14].

Budget and schedule constraints are frequently decisive, particularly for small projects. Manual demolition tends to incur lower plant costs but higher labour costs per unit of material removed than mechanical methods. In high-wage economies, manual methods are generally reserved for specialised or heritage applications. Schedule pressure consistently favours mechanical methods given their higher productivity [6][2].

3. 6 Safety Considerations by Method

The safety risk profile of demolition varies substantially between manual and equipment-based methods. Across all methods, the principal hazards are: (1) structural instability and uncontrolled collapse; (2) falls from height; (3) struck-by incidents involving falling materials, swinging plant, or reversing vehicles; (4) contact with hazardous substances; and (5) exposure to excessive noise and vibration. The relative prominence of each hazard category shifts with the demolition method employed.

In manual and hand-tool demolition, the greatest risks arise from structural instability—specifically, the risk that the partially demolished structure will collapse unexpectedly due to premature removal of a load-bearing element or a concealed defect. Falls from height represent a secondary but significant risk where operatives work at upper-storey levels without adequate edge protection or working platforms [26][29].

Equipment-based demolition shifts the primary risk profile towards struck-by incidents involving mechanical plant. Management of exclusion zones—maintained through temporary hoarding, physical barriers, and supervision of plant operators—is the primary control measure. Plant operator competence, including knowledge of structural sequences and material behaviour under hydraulic impact, is critical [3][17].

Selective deconstruction presents a distinctive risk profile associated with operatives working in close proximity to structural elements being progressively weakened. Unlike conventional demolition where the instability zone is relatively well-defined, selective deconstruction involves extended periods during which individual elements are partially disconnected and may be at risk of local instability. Current industry guidance on structural stability management in selective deconstruction remains limited [12][11].

3. 7 Demolition Waste and Material Recovery

A typical low-rise masonry or timber-framed residential building generates between 30 and 120 tonnes of demolition waste per 100 square metres of floor area, depending on construction type, number of storeys, and the extent of pre-demolition soft-strip activities [15][23]. The composition of this waste—principally concrete, masonry, timber, steel, glass, and mixed finishing materials—offers considerable scope for recovery and recycling if the waste stream is appropriately segregated.

On-site waste segregation is substantially more effective when integrated into the demolition method and sequence as a primary process rather than treated as a separate downstream activity. Where mechanical demolition is used, on-site segregation requires designated sorting areas, sufficient space for separate stockpiles, and operatives trained in visual material identification. The economics of on-site segregation are influenced by transport distances, gate fees at recycling facilities, and the availability of local markets for secondary materials [27][16].

Concrete rubble, typically the largest constituent by mass, can be crushed on site using a mobile crusher to produce RCA, generally suitable for road base material, drainage aggregate, or partial replacement for virgin aggregate in moderate-specification concrete. The quality of RCA depends on original concrete strength, the degree of contamination with other materials, and the extent of processing [15][14].

Recovered structural timber from timber-framed buildings can represent a valuable material stream in markets where reclaimed timber commands premium prices. However, timber treated with chromated copper arsenate (CCA) or similar preservatives cannot be reused in applications involving human contact and requires specialist disposal. Identification of timber treatment history is therefore an important component of pre-demolition assessment [10][12].

3. 8 Comparative Summary of Demolition Methods

Tables 1 and 2 provide structured comparative summaries of the demolition methods reviewed in the preceding sections. Table 1 compares the principal methods across seven performance dimensions. Table 2 presents a decision matrix linking five demolition methods to nine selection criteria.

Table 1 Comparative Overview of Manual and Equipment-Based Demolition Methods for Low-Rise Buildings

Method	Applicable Structure	Typical Equipment	Labour Intensity	Material Recovery	Relative Cost	Key Risk
Hand Tool Demolition	Single-storey	Sledgehammer, cold chisel,	Very High	High (selective)	High per m²	Worker fatigue; dust

Method	Applicable Structure	Typical Equipment	Labour Intensity	Material Recovery	Relative Cost	Key Risk
	masonry; lightweight timber	crowbar, hand saw				inhalation
Pneumatic/Hydraulic Power Tools	Brick/block walls; concrete slabs ≤150 mm	Jackhammer, chipping gun, rotary hammer drill	High	Moderate	Moderate	Noise; vibration; HAVS
Mechanical Excavator + Breaker	RC frames; masonry up to 3 storeys	Hydraulic excavator + breaker attachment	Low–Moderate	Low (mixed debris)	Low–Moderate	Proximity hazard; dust; ground vibration
Excavator + Crusher/Pulveriser	Concrete columns, beams, foundations	Concrete pulveriser or crusher jaw	Low	Moderate (concrete recycle)	Moderate	Flying debris; noise
Mini-Excavator	Constrained urban sites; internal walls	Mini-excavator ≤5 t with breaker	Moderate	Moderate	Moderate	Overhead clearance; structural stability
Selective Deconstruction	Timber-framed houses; heritage buildings	Hand tools + small power tools; pry bars	Very High	Very High	Very High (labour cost)	Falls; embedded fixings; sequence errors
Crane and Wrecking Ball	Masonry chimneys; isolated low-rise blocks	Mobile crane + cast-iron ball	Low	Very Low	Low	Swing radius; uncontrolled collapse

Source: Authors' compilation based on [3], [6], [7], [11], [17].

Table 2. Decision Matrix for Demolition Method Selection in Low-Rise Buildings

Decision Criterion	Hand Tools	Pneumatic Tools	Mini-Excavator	Full Excavator	Selective Decon.
Building structure type	Any	Any	Conc/Mas	Conc/Mas	Timber/Her.
Number of storeys	1	1–2	1–3	1–3	1–2
Site access width	>0.5 m	>0.5 m	>1.5 m	>4.0 m	>0.5 m
Adjacent building proximity	<0.5 m OK	<0.5 m OK	<1.5 m OK	<3 m caution	<0.5 m OK
Hazardous	Preferred	Feasible	Feasible	Post-abate	Preferred

Decision Criterion	Hand Tools	Pneumatic Tools	Mini-Excavator	Full Excavator	Selective Decon.
material presence					
Material recovery objective	High	Moderate	Moderate	Low	Very High
Project budget	High/m²	Moderate	Moderate	Low	Very High/m²
Schedule constraint	Slow	Moderate	Moderate	Fast	Very Slow
Occupational safety priority	Excellent	Good	Good	Moderate	Excellent

Source: Authors' compilation based on [1], [4], [12], [14], [20].

As shown in Table 1, each demolition method occupies a distinct performance space. Hand tool and selective deconstruction methods offer the highest material recovery potential and greatest selectivity, but at very high labour cost and low productivity. Equipment-based methods—particularly full-sized excavators with breaker or pulveriser attachments—offer the highest productivity and lowest cost per unit volume removed, but produce predominantly mixed waste with limited recycling value. Mini-excavators and pneumatic tools occupy intermediate positions, offering a practical compromise between productivity and material recovery in constrained site conditions.

Table 2 demonstrates that no single method is optimal across all selection criteria. The full hydraulic excavator performs well on productivity, cost, and schedule criteria but poorly on site access, adjacent structure risk, and selective material recovery. Selective deconstruction performs strongly on material recovery, safety, and hazardous material management but is poorly suited to tight schedules or limited budgets. The decision matrix underscores the context-dependent nature of demolition method selection and the importance of systematic multi-criteria assessment at the pre-demolition planning stage.

3. 9 Critical Assessment of Method Applicability in Developing-Country Contexts

The weight of evidence reviewed in the preceding sections originates predominantly from studies conducted in high-income countries characterised by formal regulatory frameworks, established demolition contracting industries, and ready access to modern mechanical plant. A critical assessment of method applicability in developing-country settings—which account for the majority of global low-rise demolition activity—reveals significant and systematic divergence from the patterns described in the mainstream engineering literature.

In developing-country urban and peri-urban contexts, several structural and operational conditions systematically favour manual demolition methods over equipment-based approaches, independent of cost considerations alone. First, the predominance of unreinforced load-bearing masonry construction in low-income residential buildings—characteristically built with locally produced fired clay bricks and weak lime or low-strength cement mortar—renders the structure particularly amenable to hand tool demolition. Critically, this construction typology also facilitates intact brick recovery, which constitutes a primary economic motivation for demolition in settings where reclaimed building materials command significant value in local secondary markets [2][5]. This dynamic directly inverts the cost-benefit relationship encountered in high-income contexts: the labour intensity of manual demolition is not merely accepted as a constraint but actively valued as a means of generating material recovery income that partially or wholly offsets labour costs.

Second, the plot configurations characteristic of historic urban cores, kampung settlements, and high-density informal housing areas in Southeast Asia, South Asia, and Sub-Saharan Africa—narrow frontages, minimal setbacks, and irregular access geometry—frequently preclude the physical deployment of full-sized hydraulic excavators requiring a working width of four to six metres [24][20]. In these settings, mini-excavators and hand tools are not a preference but an operational necessity imposed by site geometry. Third, the near-total absence of formal landfill gate fees and organised waste management infrastructure in many developing-country municipalities eliminates the principal financial incentive—avoided disposal cost—that underpins the economic case for on-site waste segregation in high-income settings. Under these conditions, the economic calculus governing method selection is structurally different from the models developed and validated in European or Australian research.

The relative economics of manual versus mechanical demolition in low-income settings must therefore be evaluated against local wage rates, plant hire costs, fuel prices, and secondary material market values rather than by applying benchmarks derived from developed-country practice. Research by Umar et al. [2] and Ngo et al. [5] documents the persistence of informal manual demolition in Southeast Asian cities not as a default outcome of resource poverty but as a locally rational response to material recovery incentives, physical site constraints, and labour market conditions. This finding carries direct implications for policy: efforts to improve low-rise demolition practice in developing countries that focus exclusively on promoting mechanical equipment adoption—without addressing the material recovery market infrastructure that makes manual methods economically rational—are likely to be ineffective and may even be counterproductive.

A further critical dimension is the practical absence of occupational safety regulation enforcement in informal demolition settings. The safety risk profiles described in Section 3.6 presuppose an institutional environment in which minimum personal protective equipment standards, exclusion zone management protocols, and operator competence requirements are operative and enforced. In informal demolition practice, none of these conditions can be assumed. The design of effective safety interventions for this sector therefore requires not the direct transfer of technical guidance documents from high-income regulatory contexts—which may be irrelevant to the tools, materials, and institutional conditions present—but the co-development of context-specific frameworks adapted to informal demolition practice. This represents both a research priority and a practical challenge that the engineering and occupational health communities have barely begun to address systematically.

These observations collectively underscore the importance of avoiding uncritical generalisation from the existing research base. A demolition method selection framework validated for a European urban regeneration project may perform poorly when applied without adaptation to a peri-urban setting in Indonesia, Senegal, or Colombia. Engineering guidance for demolition practice in developing countries must be grounded in empirical research conducted within those contexts, accounting for the specific material conditions, site typologies, economic structures, and regulatory environments that characterise them.

4. KNOWLEDGE GAPS AND RESEARCH PRIORITIES

Despite the practical significance of low-rise building demolition, a review of the available literature reveals several substantial gaps in current knowledge.

First, there is a marked geographical imbalance in demolition research, with the majority of published studies originating from Europe, North America, Australia, and China. Low-rise demolition in Sub-Saharan Africa, South and Southeast Asia, and Latin America—where this activity is most prevalent in informal settings—is substantially under-researched. Research addressing informal labour practices, limited equipment availability, and weak regulatory frameworks in developing countries constitutes a priority need [5][2].

Second, demolition waste management strategies have been assessed primarily in terms of landfill diversion rates rather than the quality and economic value of recovered materials. More granular data on waste composition by building typology, age, and condition would substantially improve waste management planning [15][16].

Third, the occupational health outcomes of demolition workers—including long-term respiratory disease, musculoskeletal disorders, and noise-induced hearing loss—remain poorly documented, particularly where occupational health surveillance systems are underdeveloped. Longitudinal epidemiological studies of demolition worker health would provide a more robust evidence base for exposure control strategies [18][19].

Fourth, the application of digital tools—including BIM, drone survey, and IoT-based structural monitoring—to low-rise demolition planning and execution has received limited research attention. Even modest improvements in planning quality through digital tools could yield substantial aggregate benefits. Research into the cost-effectiveness of these tools for small-scale demolition contexts is warranted [8][25].

Finally, there is a need for more systematic comparative evaluation of selective deconstruction versus conventional mechanical demolition, incorporating both environmental life cycle assessment and economic cost-benefit analysis. Such studies would provide a more robust basis for policy and regulatory decisions [27][11].

5. CONCLUSION

This systematic review has provided a comprehensive examination of the principal manual and equipment-based demolition techniques applicable to low-rise buildings, encompassing hand tool methods, pneumatic and hydraulic power tools, hydraulic excavators with various attachments, mini-excavators, and selective deconstruction. Each method has been analysed in terms of its technical characteristics, operational requirements, safety implications, waste generation profile, and economic performance.

The structural typology and material composition of the building are the primary technical determinants of demolition method suitability. Timber-framed structures offer the greatest potential for selective deconstruction and material recovery; RC frames require mechanical plant for productive demolition; and load-bearing masonry is amenable to a range of methods depending on scale, access, and recovery objectives. Site access constraints—particularly prevalent in dense urban environments and informal settlements—frequently represent the binding practical constraint on method selection.

The review highlights the inherent tension between productivity and material recovery in all demolition method decisions. The fastest and cheapest methods produce the most mixed and least recoverable waste, while the methods achieving the highest material recovery are the slowest and most costly. Bridging this trade-off requires not only technical innovation but also regulatory frameworks, economic incentives, and market infrastructure that make high-recovery approaches financially viable.

Safety considerations are pervasive across all demolition methods. Structural instability, falls from height, struck-by incidents, and hazardous material exposure are the dominant risk categories, with their relative prominence shifting according to the method employed. The consistent finding across the occupational health and safety literature is that risk management outcomes are as much a function of management quality, workforce competence, and regulatory enforcement as of the technical method itself.

5. 1 Limitations of This Review

Several limitations of the present review should be acknowledged in order to support appropriate interpretation of its findings. First, the literature search was restricted to publications in the English language, potentially excluding technically significant research published in Indonesian, Portuguese, French, Mandarin, Arabic, or other languages relevant to the developing-country contexts that this review specifically emphasises. Second, the quantitative performance data cited—including material recovery rates, productivity figures, and relative cost estimates—are drawn from studies conducted under specific national conditions and should not be generalised to other contexts without local calibration against regional labour costs, plant hire rates, and secondary material market values. Third, the absence of a formal statistical meta-analysis reflects the substantial heterogeneity of study designs, performance metrics, and building typologies encountered in the source literature; the structured comparative tables presented in Section 3.8 represent a narrative synthesis rather than a statistical aggregation, and the relative performance assessments therein should be understood as directional rather than precisely quantified. Fourth, rapidly evolving practices in robotic demolition systems, real-time structural monitoring technologies, and AI-assisted pre-demolition building assessment—areas of active technological development—may have advanced beyond what the literature included in this review fully captures, and future reviews should extend their scope accordingly.

5. 2 Directions for Future Research

The knowledge gaps identified in Section 4, together with the limitations of the present review, indicate several specific and actionable priorities for future research. First, the development of context-specific demolition method selection tools—calibrated to the regulatory, economic, material, and site-access conditions of Southeast Asia, Sub-Saharan Africa, and Latin America—represents the most immediate practical research need. Such tools should be validated through empirical field studies rather than adapted from high-income frameworks without contextual adjustment. Second, longitudinal occupational health investigations of demolition workers in informal and semi-formal settings—tracking multi-year incidence of silicosis, musculoskeletal disorders, noise-induced hearing loss, and HAVS through cohort or register-based study designs—are essential to establishing the evidence base for targeted and cost-effective health interventions. Third, comparative environmental life cycle assessment studies examining selective deconstruction versus conventional mechanical demolition across diverse national regulatory and market contexts would provide a substantially more robust empirical foundation for sustainability-related policy and regulatory decisions. Fourth, pilot investigations of semi-mechanised selective deconstruction approaches—combining compact power tools with digital material inventory tracking and BIM-based pre-demolition audits—for application in constrained urban sites and informal settlement contexts merit dedicated research investment, as these approaches may offer a viable pathway to simultaneously improving material recovery rates and occupational safety outcomes in settings where neither is currently prioritised. Fifth, standardised waste characterisation studies—reporting demolition waste composition by building typology, age, and condition across comparable methodologies—would substantially improve the quality of waste management planning and secondary material market development in countries currently lacking granular national data.

Looking ahead, the development of more detailed context-specific guidance for low-rise demolition—encompassing method selection frameworks, safety management systems tailored to small-scale projects, and waste management protocols adapted to diverse national contexts—represents an important contribution that research and the professional community can make to improving practice. Substantially greater research attention to low-rise demolition in developing-country settings is particularly warranted, given both the scale of this activity and the significant human and environmental consequences of prevailing informal practice.

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