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Review Article

Closing construction material loops in Southern Libya: A circular economy framework for date-palm residues and demolition waste

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ABSTRACT

Construction in arid regions faces a dual resource challenge: growing demand for affordable materials and poorly connected recovery pathways for agricultural and demolition residues. Southern Libya provides a relevant context because date-palm cultivation coexists with infrastructure rehabilitation, yet reliable local waste inventories and certified secondary-material markets remain limited. This review critically integrates evidence on date-palm-derived fibers and products, construction and demolition waste recovery, circular construction governance, and life-cycle assessment to develop a regionally adaptable circular economy framework. A structured, non-exhaustive evidence synthesis was used to compare material properties, potential applications, quality risks, logistics constraints, and enabling institutions; no field sampling or laboratory testing was undertaken. The synthesis identifies distinct but complementary recovery routes: selective segregation of concrete and masonry for qualified aggregate applications, and controlled processing of suitable palm residues for non-structural panels and other bio-based products. It also reveals that moisture sensitivity, variable feedstock composition, contamination, transport distances, and absent traceability can undermine circularity claims. The principal result is a five-gate implementation framework connecting source identification, safety screening, conditioning, application-specific qualification, and monitored deployment, supported by a local material-exchange mechanism and auditable indicators. The proposed framework prioritizes verified performance and avoided environmental burdens over diversion rates alone. It offers municipalities, contractors, farmers, and technical institutions a practical research and policy agenda while identifying the measurements required before commercial adoption.

Keywords: *Circular economy, date-palm residues, demolition waste, construction materials, Southern Libya, material recovery, circular construction*

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INTRODUCTION

The construction sector is simultaneously a consumer of mineral resources, an emitter of substantial life-cycle burdens, and a generator of recoverable residues. A circular economy reframes this problem by seeking to retain material functionality for longer, prevent waste upstream, and return suitable products or secondary materials to safe use. However, the terms “recycling” and “circularity” are not interchangeable: collection can increase without replacing virgin production, while poorly controlled processing may shift burdens into energy demand, transport, health risks, or premature material failure. Kirchherr, Reike, and Hekkert (2017) documented this conceptual inconsistency; Pomponi and Moncaster (2017) consequently argued for life-cycle and multiscale perspectives tailored to the built environment. These distinctions are especially consequential when circular construction is proposed for places where environmental monitoring and materials markets are fragmented.

Southern Libya—here understood as the Fezzan region and its settlements, including the Wadi al-Shati area—offers a compelling planning context rather than a quantified case dataset. Oasis agriculture has long included date palms, while construction, rehabilitation, and demolition generate potentially reusable mineral materials. Published Libyan studies have addressed post-conflict waste governance and construction-demolition recycling through frameworks and modeling, rather than establishing a verified inventory for each southern municipality (Ali & Ezeah, 2017; Shiboub & Assaf, 2019). Recent national work has also evaluated management options by multicriteria decision analysis (Alossta, Eltariki, Elmansouri, & Badi, 2024). None of these sources is treated here as a validated measurement of date-palm residues or demolition waste specifically available in Wadi al-Shati in 2026.

Two material streams warrant a joined investigation. Date-palm maintenance can produce leaflets, fibers, fronds, midribs, and other lignocellulosic fractions whose composition, moisture content, and dimensional stability differ by origin and preparation. Separately, demolition material can contain concrete, masonry, mortar, asphalt, metals, glass, gypsum, soil, coatings, and potentially hazardous components. Date-palm-based construction composites promise renewable inputs and possible thermal benefits but can suffer moisture uptake and reduced mechanical performance. Recycled demolition aggregates can preserve mineral resources, yet adhered mortar, variable grading, impurities, and application-specific durability requirements complicate substitution (Bamaga, 2022; Nedeljković, Visser, Šavija, Valcke, & Schlangen, 2021; Piccinali, Diotti, Plizzari, & Sorlini, 2022).

The central research problem is thus not whether two wastes can theoretically be recycled. It is how their recovery can be organized as a safe, traceable, economically plausible regional system that links material supply, processing capability, engineering demand, and verifiable environmental value. This paper asks: (i) which pathways for these residues are supported by the external evidence and for what applications; (ii) which technical, health, logistical, and institutional conditions delimit responsible adoption; and (iii) how an integrated circular-construction framework can translate the evidence into a feasible sequence for Fezzan decision-makers?



Accordingly, the paper contributes a critical cross-stream synthesis, a condition-based route-to-application matrix, an explicit five-stage qualification process, and a multi-actor governance model. Its claimed results are analytical outputs—not locally measured waste

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tonnages, strength tests, carbon savings, or investment returns. This distinction keeps the study aligned with a review-article format and prevents transfer of experimental findings from other climates and mixtures into unsupported local performance claims.

LITERATURE REVIEW

The literature distinguishes narrow end-of-pipe recovery from more consequential circular strategies: avoidance of unnecessary material use, extension of component life, design for adaptability and disassembly, selective recovery, reuse, and recycling. A demolition recycler may produce an aggregate that is technically marketable yet environmentally unfavorable if extensive hauling, crushing, washing, and quality loss outweigh virgin-material displacement. Conversely, preserving components for reuse can retain more embedded processing value than comminution, provided provenance and safety are established. Ghisellini, Ripa, and Ulgiati (2018) reviewed the environmental and economic trade-offs across the construction sector, while López Ruiz, Roca Ramón, and Gassó Domingo (2020) organized interventions across the construction life cycle. Both perspectives indicate that material recovery must be embedded in design, procurement, and end-use decisions.

Empirical syntheses have emphasized the organizational dimension often omitted from waste-product studies. Purchase et al. (2022) reviewed lessons and barriers in construction-demolition circularity; Oluleye, Chan, Saka, and Olawumi (2022) identified a broad research agenda around its indicators; Charef, Lu, and Hall (2022) synthesized the transition across construction assets; and Soto-Paz, Arroyo, Torres-Guevara, Parra-Orobio, and Casallas-Ojeda (2023) compared conditions in emerging and developed economies. Together these works caution against transplanting industrial-country systems without adjustment for policy enforcement, sorting infrastructure, supply continuity, and market trust. A southern Libyan strategy should therefore start from feasible capabilities and quality control rather than assume a mature secondary-material supply chain already exists.

At the building scale, the hierarchy also includes future recoverability. Pristerà, Tonini, Lamperti Tornaghi, Caro, and Sala (2024) catalogued design-for-deconstruction options, and the International Organization for Standardization (ISO, 2020) codified principles for disassembly and adaptability in ISO 20887. Such approaches are useful when new buildings are designed, but legacy demolition waste is already mixed; immediate priorities differ. For existing stock, documented inventories, source segregation, controlled sorting, and realistic specifications are more actionable than retroactively applying design-for-disassembly principles. Both pathways should be considered complementary rather than competing.

Date-palm residues are not a single material. Leaf-fiber bundles, leaflets, petioles, fronds, and processing by-products can differ in fiber aspect ratio, cellulose and lignin fractions, extractives, soluble salts, bulk density, and water sorption. Agricultural management and preparation also influence contamination by soil, pests, and decay. Consequently, generic percentages imported from a single experiment cannot characterize a regional feedstock. A more responsible circular design begins by specifying the fraction used, establishing a moisture and cleaning protocol, and matching the prepared input to the performance demands of a particular product.



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Bamaga (2022) reviewed date-palm fibers in mortar and concrete and found attractive lightweight and thermal-related properties, while also documenting possible reductions in fresh and hardened mechanical performance. Experimental work by Althoey et al. (2022) examined date-palm fiber inclusion in high-strength concrete and reported changes in strength and serviceability responses dependent on dosage and comparison material. These findings do not establish that untreated Fezzan fibers will improve a structural concrete mix: the cementitious matrix is alkaline, organic fibers are moisture sensitive, and long-term behavior depends on pre-treatment, dispersion, dosage, exposure, and binder chemistry. Particularly where potable water and treatment chemicals are scarce, the environmental cost of preparation is part of the decision, not an externality.

A material hierarchy emerges from this evidence. Possible low-risk investigation routes include non-load-bearing fiberboards, insulation layers, interior partition materials, or fiber-assisted plaster formulations, each requiring application-specific tests. The thermal appeal of plant biomass in hot climates is significant but must be tested jointly with fire performance, fungal susceptibility, indoor air quality, water uptake, and service life. Treating agricultural residues as an inherently “green” cement replacement is a conceptual error; ash chemistry, calcination energy, loss on ignition, salts, and pozzolanic reactivity must be established before substitution. Likewise, using palm biochar in construction products is a research hypothesis until material safety and engineering performance are verified.

The circularity claim also depends on alternative uses. Palm pruning material may already serve as household fuel, fodder, mulching, crafts, or other local functions. Diverting such material into a building product would not represent a net benefit if it simply displaces a useful local application or raises procurement pressure. A regional material census should therefore record generated, currently used, and otherwise discarded fractions separately. This distinction, familiar from life-cycle thinking and biomass management, is indispensable to avoid double-counting “available waste”.

Demolition waste quality depends on source and deconstruction practice. Clean concrete fragments can be processed into recycled aggregate after crushing, screening, contamination control, and suitability testing. Mixed masonry, gypsum, soils, coatings, metals, and organic debris generate distinct streams with different value and risk. Nedeljković et al. (2021) explained the physical and chemical complications of fine recycled concrete aggregates, while Piccinali et al. (2022) documented that recycled concrete aggregate is commonly more homogeneous than mixed recovered aggregate. Thus, a “one-bin, one-product” approach cannot form a credible technical foundation.

Recycled aggregate should not automatically be specified for structural applications. Residual adhered mortar may increase water absorption and porosity; the grading and contaminant content influence compaction, workability, strength, permeability, and durability. The safest initial outlets to study locally may include qualified unbound road layers, bedding, certain paving elements, and low-risk non-structural components. Even these applications require compliance with project specifications and geotechnical, durability, and environmental checks. Structural concrete requires more demanding quality assurance and an explicit engineering approval route. These conclusions align with broad reviews of applications and environmental performance (Ginga, Ongpeng, & Daly, 2020; Piccinali et al., 2022).



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Safety is a prior condition, not a later optimization. Demolition sources may contain asbestos-containing products, lead-based coatings, chemical residues, excessive gypsum or sulfate, or waste with uncertain provenance. This review does not presume that these substances are present at any specific southern Libyan site; rather, the possibility mandates source audits and appropriate testing. Hazardous/unidentifiable fractions must be removed from proposed material loops and managed by authorized pathways. A policy that rewards tonnage diversion without protecting workers, residents, and receiving soils may promote the wrong operational outcome.

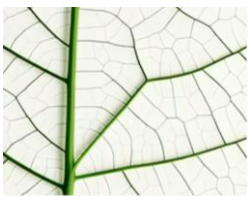
Environmental superiority likewise remains conditional. Zhang et al. (2019), Alzard, El-Hassan, and El-Maaddawy (2021), and Hasheminezhad, King, Ceylan, and Kim (2024) demonstrate why recycled-aggregate life-cycle assessments depend on mix design, allocation, transportation, energy supply, service life, and the functional unit. A road subbase produced from local recovered aggregate may be advantageous under one haul-distance and quality scenario yet inferior under another. Claims of avoided emissions or carbon-neutral products in Fezzan therefore require an explicit local inventory and comparative functional equivalence.

Libyan scholarship provides critical contextual grounding without delivering a finished Fezzan circular construction market. Ali and Ezeah (2017) considered post-conflict waste-management constraints and proposed a national framework; Shiboub and Assaf (2019) investigated a system-dynamics model of construction-demolition recycling. The later decision-model study by Alossta et al. (2024) assessed waste-management alternatives in Libya. These studies collectively demonstrate that institutional coordination, financing, collection, and markets matter as much as the processing technology. Their national or other-city findings cannot, however, be interpreted as measured flow inventories or processing performance for Wadi al-Shati.

The gap addressed here is the intersection of two typically separate streams: mineral demolition debris and agricultural palm residues. Most construction-demolition circular-economy reviews evaluate recovered building materials, whereas palm studies usually evaluate isolated composite formulations. The present contribution is not to claim a new cement product, nor to reproduce multicriteria ranking with fabricated stakeholder weights; it is to formulate explicit rules that connect the streams into shared collection, quality assurance, procurement, and governance pathways. The proposed integration remains a hypothesis for operational evaluation. Its success requires future location-specific evidence.

Table I. Critical synthesis of literature and its relevance to the Fezzan framework

Evidence area	Representative sources	Transferable insight	Critical limitation
Circular construction strategy	Kirchherr et al. (2017); Pomponi & Moncaster (2017)	Prioritize prevention, reuse, and auditable value retention.	Definitions and metrics vary across studies.
Demolition material recovery	Ginga et al. (2020); Piccinali et al. (2022)	Separate concrete from mixed fractions; qualify end use.	Results depend on contamination and specifications.
Date-palm composites	Bamaga (2022); Althoey et al. (2022)	Bio-based non-structural applications merit investigation.	Durability and water sensitivity constrain claims.



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Environmental comparison	Zhang et al. (2019); Hasheminezhad et al. (2024)	Use functional equivalence and transparent boundaries.	Transport and process energy can reverse benefits.
Libyan management context	Ali & Ezeah (2017); Alossta et al. (2024)	Governance and prioritization are central.	Not site-specific inventories for Wadi al-Shati.

METHOD

This study uses a structured critical narrative review followed by conceptual framework synthesis. It is not a systematic review or a meta-analysis, and it makes no claim to exhaustive database coverage or pooled statistical effect sizes. The review drew on discoverable, identifiable peer-reviewed publications and institutional standards available through October 2026, with foundational sources retained when they established key concepts. Focused search expressions combined “circular economy”, “construction and demolition waste”, “date palm fiber”, “date palm waste”, “recycled aggregate”, “life cycle assessment”, “Libya”, “Fezzan”, and “built environment”. Bibliographic and journal/publisher records were used to cross-check source identity and relevance.

Sources were purposively selected when they contributed to at least one of four needs: (a) conceptual and governance definitions of circular construction; (b) evidence on physical and engineering limitations of palm-derived materials; (c) recovery and qualification of mineral demolition materials; or (d) Libyan implementation conditions and life-cycle methods. Preference was given to peer-reviewed reviews, foundational empirical papers, published country-context studies, and applicable standards. The screening excluded unrelated biomass markets, untraceable statistics, unsupported manufacturer claims, and studies whose material context could not plausibly inform construction choices. Because no comprehensive database export and full-text screening log were created, numerical PRISMA-style identification and exclusion counts are deliberately not presented.

3.1 Analytical coding and evidence-status rules

Each reviewed contribution was interpreted using a five-part extraction grid: origin and composition of material; processing or recovery step; claimed construction application; reported benefit and performance risk; and barriers to contextual transfer. Evidence was then compared across streams to distinguish generally supported principles from application-specific claims. Source-derived observations are reported as such. Framework design choices, candidate pilot activities, indicators, and sequencing rules are explicitly presented as proposals derived through reasoning, not as experimentally validated findings.

Transferability was assessed qualitatively using four questions: Is the incoming feedstock sufficiently similar to the materials studied? Does the application require a performance standard that can be checked locally? Can the environmental advantage survive realistic transport and processing conditions? Is there an accountable actor with responsibility for quality and records? A negative or unknown answer does not prove a technology unsuitable; it means the route remains conditional. This is important for preventing weak evidence from



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being reclassified as proof of feasibility merely because an application appears promising elsewhere.

3.2 Framework construction and indicator design

The framework was assembled by placing material pathways within a stage-gate lifecycle of five checkpoints (G0–G4), followed by a governance loop. The design follows general concepts of circular value retention (Kirchherr et al., 2017), construction lifecycle integration (López Ruiz et al., 2020), and disassembly and material accountability (ISO, 2020). The resulting gates address origin documentation, health and environmental exclusions, controlled processing, intended-use qualification, and monitored deployment. The gates are procedural recommendations and do not substitute for a licensed laboratory, building code, site investigation, or regulatory permit.

For future quantification, the proposed system distinguishes a recovery ratio from confirmed circular substitution. Let M_{col} denote collected eligible mass, M_{qual} the mass satisfying technical and safety requirements, and M_{used} the verified mass installed in an approved application. Candidate metrics are qualification yield $Y_q = M_{qual} / M_{col}$ and verified reuse ratio $R_v = M_{used} / M_{col}$, evaluated for the same material stream and period, assuming $M_{col} > 0$. Neither ratio alone proves climate benefit. For functional-unit comparisons, net avoided impact is defined conceptually as $I_{avoid} = I_{baseline} - I_{recovery}$, where both alternatives deliver an equivalent service life and include collection, preparation, transport, replacement, and end-of-life. These are analytical definitions, not equations calculated from Fezzan measurements.

A related techno-economic decision rule is that a proposed circular route should proceed only when applicable safety and technical tests are passed and the benefits remain credible after sensitivity analysis on recovery yield, transport, energy, water, and replacement lifetime. For comparison, a nonstructural product may be assessed per square meter of panel meeting specified thermal, strength, fire, and durability functions over a fixed service life; an unbound road layer can be compared per cubic meter or kilometer of layer meeting identical load-bearing and durability requirements. A mass-only reference unit would be inadequate whenever the two materials deliver different performance.

Table 2. Review coding categories and interpretation rules

Coding dimension	Evidence extraction question	Interpretation
Feedstock identity	Which fraction, condition, and source are described?	No automatic equivalence between different palm fractions or demolition mixtures
Processing burden	Which sorting, drying, crushing, washing, or binder inputs are needed?	Require life-cycle inventory before calling a route environmentally superior
Engineering suitability	What application and tests are reported?	Restrict proposed deployment to demonstrably qualified uses.
Environmental safeguards	Are contamination, leaching, fire and moisture risks addressed?	Unknown status triggers screening or exclusion



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Governance viability	Who owns, transports, certifies and buys the recovered material?	Identify accountable operators and traceable transactions
Local transferability	Were samples or conditions from Fezzan examined?	External evidence is a hypothesis, not a local measurement

RESULT

The first result of the synthesis is an integrated architecture in which agricultural and mineral streams retain separate technical treatment while sharing logistical and institutional infrastructure. Figure1 illustrates the distinct recovery chains. Palm residues require fraction classification, cleaning, controlled moisture management, and product-specific conversion. Demolition inputs require a pre-demolition audit, selective removal of risky components, source segregation, crushing or grading where relevant, and suitability checks. Both streams can then enter a regional material-exchange system that matches verified specifications to actual contractors and buyers. The point of integration is primarily governance and market coordination, not the physical mixing of two uncontrolled wastes.

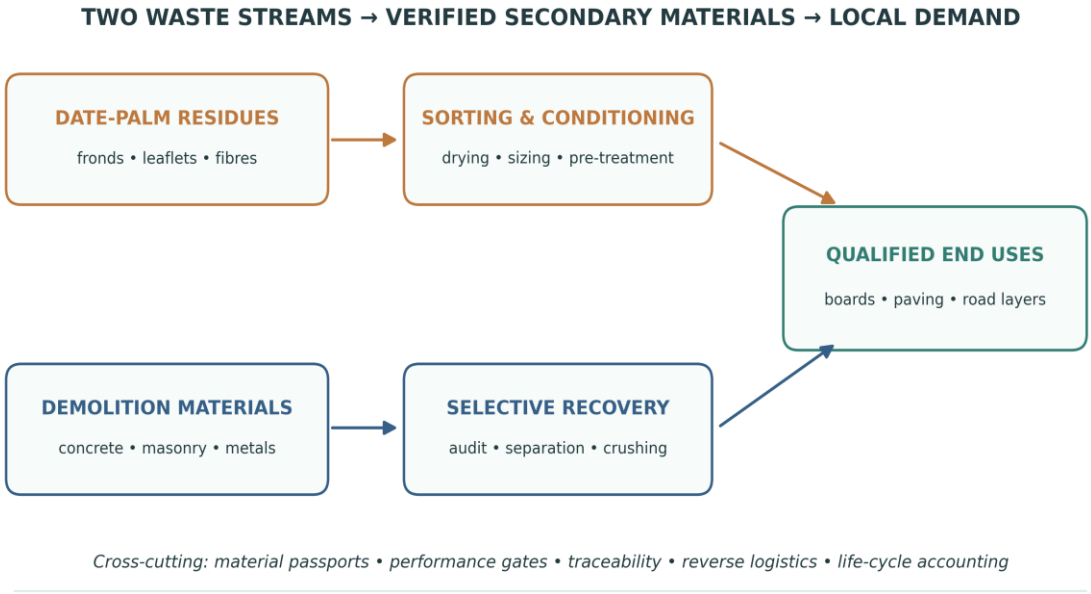


Figure 1. Proposed dual-stream circular material architecture

This separation is necessary because the technology risks differ. Fibers may be combustible, hygroscopic, and biologically degradable; recycled aggregate may carry adhered mortar, salts, fine particles, or contaminants. Shared contracts and collection routes can reduce information and transaction barriers, but a processing site must not co-mingle dissimilar fractions without an engineering reason and safe containment. The proposal also preserves opportunities for direct reuse of intact building components when a quality assessment permits, because pulverizing usable components needlessly destroys retained value (Pristerà et al., 2024).



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Table 3. Proposed application pathways and mandatory qualification conditions

Input fraction	Possible circular outlet	Required checks before approval	Present evidence status
Separated concrete rubble	Recycled unbound road layer, bedding, selected nonstructural units	Grading, compaction/CBR as relevant, contaminants, leaching, project specification	Supported class of use internationally; locally unverified
Mixed concrete and masonry	Selected low-risk fills or masonry-based products	Composition, gypsum/sulfate, contaminants, moisture, service suitability	Highly variable; use requires careful segregation
Reusable building elements	Direct reuse or refurbishment	Condition survey, dimensions, remaining strength, provenance	High value-retention potential; case dependent
Clean date-palm fiber/leaf fractions	Insulating/partition boards or fiber mortar research	Moisture, fire, fungal resistance, mechanical strength, binder and emissions	Research pathway; no Fezzan product certification
Palm ash or biochar	Exploratory mineral/binder or filler applications	Ash chemistry, soluble salts, reactivity, calcination impact, leaching	Research hypothesis; not a pre-specified cement substitute
Hazardous or unknown material	Controlled specialist handling; exclude from circular outlets	Hazard identification, regulatory authorization, safe disposal	Explicit exclusion, not a circular product

The second result is the five-gate qualification sequence shown in Figure 2. G0 records a material's origin, estimated stream, and current use. G1 screens for hazardous, incompatible, or unknown constituents. G2 establishes controlled and documented conditioning, including sorting and size reduction where appropriate. G3 requires product-specific evidence that the secondary material satisfies the receiving application and environmental rules. G4 records the actual installation or sale, monitors performance, and gathers post-use feedback. The sequence is deliberately asymmetric: beneficial outcomes cannot bypass safety checks. A failed gate redirects a stream toward further treatment, a different use with appropriate technical controls, or safe disposal.

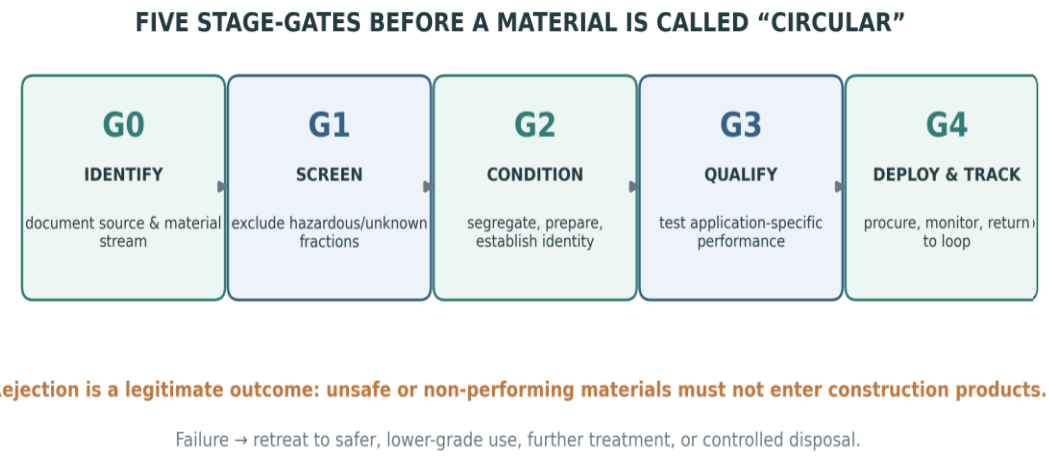


Figure 2. Proposed five-gate technical and environmental qualification system



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For example, a segregated concrete stockpile might pass identity screening yet fail a road-layer specification due to unacceptable fines or sulfate concentration; a date-palm fiberboard might reach adequate thermal performance but fail a fire or humidity requirement. Neither should be counted as qualified circular construction material. In contrast, a stockpile meeting a specified low-risk unbound application and demonstrating acceptable environmental safeguards could enter a monitored pilot. Under these rules, the term "recovered" describes the processing stage, whereas "verified reuse" requires successful application. This distinction addresses a recurrent mismatch between diversion statistics and circular performance.

4.1 Decision matrix for Fezzan pilot priorities

The synthesis yields a qualitative prioritization, not a calibrated numerical ranking. The matrix in Table 4 combines foreseeable application importance, technical conditionality, and proof requirements. Pathways labelled "candidate first pilots" are recommended for consideration because they offer testable, bounded uses, not because their cost or strength has already been demonstrated in Libya. Pathways labelled "research intensive" have more complex product approval and long-term durability uncertainties. This cautious approach intentionally avoids fabricated waste-generation figures, material-strength results, or benefits attributed to a non-existent demonstration plant.

Table 4. Illustrative prioritization of circular pilots

Pilot concept	Why investigate?	Main uncertainty	Suggested phase
Source-separated concrete for unbound layers	Matches large-volume civil works and avoids demanding structural approval.	Gradation, contamination, transport economics	Early feasibility pilot, after tests
Documented reuse of intact elements	Can preserve manufacturing value with limited processing	Provenance, load capacity, condition	Early selective-reuse pilot
Palm-fiber nonstructural boards	Possible bio-based product relevance in hot regions	Fire, moisture, durability, binder impact	Prototype/standardization research
Mixed rubble in structural concrete	Large potential market but high performance consequence	Heterogeneity, long-term durability and liability.	Deferred; rigorous validation first
Date-palm ash as cement replacement	Potential clinker displacement but uncertain chemistry	Pozzolanic activity, salt content, fuel and emissions	Laboratory-first research only

4.2 Governance and material information infrastructure

The third design output is an organizational arrangement that makes waste-to-product transactions identifiable and accountable. Figure 3 proposes a collaboration among municipal waste authorities, agricultural producers, building owners and demolishers, licensed processors, contractors, and local technical institutions. Municipalities can support route designation and reporting; contractors can disclose specifications and procurement needs; processors can maintain batch records and test certificates; the Higher Institute and partner laboratories can help draft measurement protocols and independently verify pilot evidence. None of these relationships is claimed to exist today as a functioning partnership: they represent governance functions to be negotiated.



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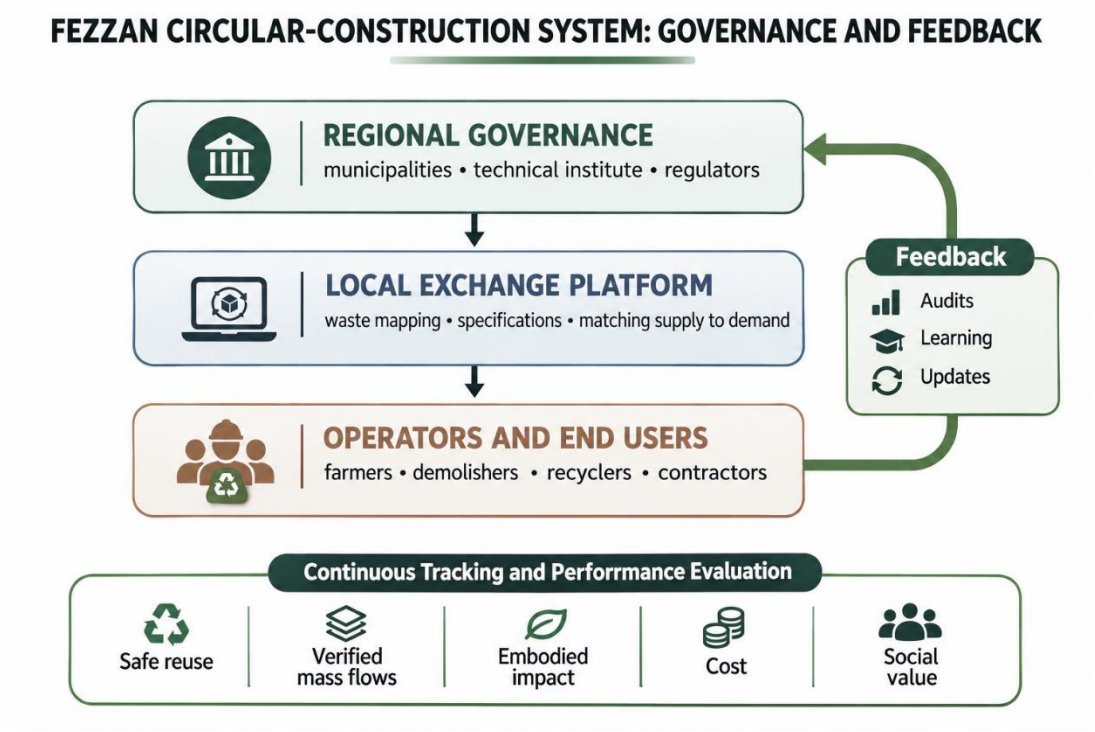


Figure 3. Proposed regional governance and feedback system

A minimal material passport would document a lot identifier, origin, input mass, declared fraction, prohibited contaminants screened, processing date, test references, intended application, receiving party, and end-use quantity. Records need not initially depend on expensive digital infrastructure: standardized paper forms and a shared spreadsheet can provide traceability where connectivity is unreliable. Digital exchanges become useful only once materials, responsibilities, and quality gates have been defined. A transparent material-passport practice also allows regulators to investigate failures and separates certified recovery from undocumented disposal.

Table 5. Minimum monitoring dashboard for a future Fezzan pilot

Indicator	Definition/unit	Reason for collection	Interpretation safeguard
Collection by stream	Tons per material fraction and period	Establish an actual baseline inventory.	Do not equate collected tons with recycling
Qualification yield	Qualified mass / collected eligible mass (%)	Measure technical and safety acceptance.	Use comparable mass boundaries
Verified deployment	Mass installed with confirmed receipt (tons)	Track displacement from stockpile to project.	Requires end-user documentation
Virgin displacement	Equivalent primary material avoided (kg or m^3)	Link flows to resource outcomes.	Correct for quality and function
Net climate effect	kg CO_2-eq per equivalent functional unit	Check process and transport trade-offs.	Only after transparent life-cycle model
Water and energy intensity	m^3 and kWh per ton of usable output	Identify resource-intensive processing.	State electricity and water boundaries



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Compliance incidents	Count of safety or specification failures	Maintain protection and accountability.	Report failures, not only success
Unit delivered cost	LYD per certified functional unit	Evaluate affordability and procurement.	Include testing, sorting, rejects, and hauling

The final synthesis is a staged pathway in which knowledge acquisition precedes capital-intensive investment. Phase A establishes a baseline through stakeholder identification, a limited waste-stream audit, and a legal/standards review. Phase B tests short-listed material routes at appropriate laboratories, maps prospective users, and develops a procurement specification. Phase C demonstrates one or two small applications with traceability and environmental monitoring. Phase D scales only successful pathways after validating demand, compliance, maintenance performance, and financing. The durations are intentionally unspecified because local staffing, permits, and resources have not been assessed. This is a program-design output, not a claim that implementation has begun.

Table 6. Proposed staged implementation roadmap

Stage	Deliverable	Decision to advance	Responsible partnership
A — Baseline	Verified inventory, stakeholder register, preliminary hazards	Reliable sources, permitted handling route	Municipalities, farms, contractors, institute
B — Qualification	Batch tests, material specs, cost and impact model	Application-level technical/safety acceptance	Technical institute, laboratories, processors
C — Demonstration	Small monitored nonstructural/road-layer pilot	Documented performance, demand and traceability	Road agency or client, contractors, regulators
D — Scaling	Procurement policy, quality scheme, material marketplace	Replicable demand & sustainable financing	Public/private construction value chain

DISCUSSION

The central theoretical contribution is the distinction between the existence of a recoverable residue and the completion of an accountable material loop. Circular economy narratives often describe streams as “resources” without explaining the technical pathway by which a heterogeneous input becomes a verified product. The proposed dual-stream framework integrates source identification, product qualification, reverse logistics, end-user demand, and feedback. This broadens a material-recovery approach into a socio-technical system that can reject unsafe materials and learn from deployment. It also operationalizes the view that circularity depends on coordinated micro- and meso-level practices, an issue raised by Pomponi and Moncaster (2017) and Charef et al. (2022).

Importantly, the physical co-processing of palm biomass and demolition rubble is not treated as a prerequisite. Combining their management systems can generate value through shared



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information infrastructure, coordinated transport where hygienic and technically appropriate, purchasing arrangements, testing services, and quality labeling. This is more defensible than inventing a novel hybrid composite without performance data. Where scientifically justified and later validated, palm-derived fibers might enter selected mineral-based nonstructural products, but such a composite remains an experimental research question rather than a proven result of this paper.

Aridity creates opportunities and constraints simultaneously. Hot climates support interest in thermally resistive building envelopes, but harsh solar exposure, thermal cycles, dust, and water scarcity can limit durability and safe processing. For date-palm products, drying demands and binder choice may affect operational feasibility, while moisture-induced deterioration and fire classification still matter despite generally dry conditions. For mineral recycling, avoiding quarry extraction is attractive, but crushers require energy, particle washing may require water, and long-distance transport can outweigh benefits. A valid environmental comparison should therefore follow transparent life-cycle boundaries (ISO, 2006) and should not assume that waste origin guarantees low climate impacts.

The strongest immediate use case may be a lower-consequence, specification-controlled infrastructure application rather than a structural claim. Sorting concrete and masonry at source can improve feedstock homogeneity, reduce hazardous impurities, and lower downstream rejection. Recycled material could then be tested against local road-layer requirements where alternatives and logistics make sense. In parallel, palm-fiber product research might target modular boards for non-load-bearing roles after fire, moisture, and strength qualification. The same region can support both streams, but the evidentiary burden must remain different for each application. This follows the performance caution of Bamaga (2022) and the aggregate-quality distinction of Piccinali et al. (2022).

International evidence suggests that access to sorting facilities alone rarely guarantees a circular transition. Procurement demand, product standards, stable feedstock supply, contamination responsibility, and maintenance feedback influence whether secondary materials replace virgin inputs. Libyan studies already highlight system design and prioritization needs (Ali & Ezeah, 2017; Shiboub & Assaf, 2019; Alossta et al., 2024). A targeted policy response could begin with sample material specifications, municipal sorting guidelines, pilot procurement clauses, basic audit forms, and arrangements for independent test certification. These actions are proposed as options for discussion, not descriptions of current Libyan law or institutional capacity.

Economic assessment should be based on a delivered functional unit rather than a gate price per ton. A seemingly inexpensive stockpile may require repeated crushing, failed quality tests, equipment mobilization, specialized transportation, or higher binder dosages. Public incentives that pay by recovered mass risk rewarding stockpiling or low-value downcycling. Instead, future contracts could use conditional payments linked to passing quality gates and documented use, while monitoring cost, emissions, incident rates, and resource efficiency. This aligns with life-cycle and circular performance thinking rather than isolated recycling quotas (Ghisellini et al., 2018; Hasheminezhad et al., 2024).



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To render the framework empirically testable, four propositions are advanced. P1: selective demolition and labelled collection will increase the share of batches satisfying low-risk construction specifications relative to mixed collection. P2: verified local displacement of virgin aggregate will have lower net environmental burden only below a route-dependent combination of haul distance, energy intensity, and rejection rate. P3: date-palm-derived nonstructural products can reach useful performance only after controlling fiber quality, binder compatibility, moisture behavior, and fire classification. P4: traceable procurement and clearly allocated liability will improve adoption more reliably than collection targets alone. Each proposition can be rejected or refined through appropriately designed future studies; none is presented as already demonstrated in Southern Libya.

The framework also clarifies the role of data-intensive work that lies outside this review. Municipal mass-flow audits would identify recoverable quantities and seasonal variation; geospatial analysis could compare generation points with road projects and processors; laboratory characterization would distinguish viable aggregate and biomass lots; life-cycle inventory could test climate and water outcomes; and interviews with farmers, contractors, waste managers, and regulators could determine policy feasibility. The absence of this evidence is not concealed by substituting foreign figures. Rather, the paper identifies an ordered evidence-generation agenda so that later claims can be genuinely local.

This article has four important limitations. First, it is a structured critical narrative review, not an exhaustive systematic synthesis with independent double-screening. Second, available experimental findings arise primarily outside Southern Libya; differences in feedstock chemistry, climate exposure, mineral aggregates, and construction specifications constrain direct transfer. Third, no primary surveys, waste weighing, certified tests, emissions inventories, procurement prices, or stakeholder consultations were conducted for this paper. Fourth, the framework has not been subjected to actual pilot implementation or independent decision-maker validation. Accordingly, the paper offers plausible pathways and qualification logic, not verified local performance estimates, a certified construction product, or evidence that net carbon savings have occurred.

CONCLUSION

This review demonstrates that the circular construction opportunity associated with date-palm residues and demolition materials is fundamentally a problem of coordinated material qualification, value retention, and governance, rather than a simple question of finding uses for waste. The international evidence supports investigating selective recovery of clean concrete and masonry for specification-controlled applications and evaluating suitable palm fractions for selected nonstructural bio-based products. It also shows why moisture, fire safety, contaminant content, engineering performance, transport, water use, and life-cycle allocation can invalidate poorly qualified circularity claims.



The proposed contribution for Southern Libya is a dual-stream circular economy architecture, accompanied by five sequential material gates, a route-to-application matrix, a monitoring dashboard, and a phased governance roadmap. These components integrate environmental

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science, civil materials engineering, supply-chain coordination, and public procurement. Because they are derived from published evidence rather than field investigation, they should be treated as a conceptual decision aid, not a validated local processing system.

Priority next steps are to establish small, auditable municipal inventories; identify currently used and genuinely surplus palm fractions; assess demolition contamination and traceability; run qualified laboratory tests on one low-risk mineral and one nonstructural biological route; and compare pilot alternatives with transparent life-cycle assessment and delivered-cost analysis. Local technical institutions could coordinate baseline protocols, while municipalities and contractors specify receiving applications and compliance responsibilities. Future research should then test the framework's propositions through controlled pilots and publish both failed and successful gate outcomes. Such a staged approach can support genuinely circular construction transitions without compromising safety or overstating environmental benefits.

REFERENCES

Ali, A., & Ezeah, C. (2017). Framework for management of post-conflict waste in Libya. European Scientific Journal, 13(5), 32. https://doi.org/10.19044/esj.2017.v13n5p32

Alossta, A., Eltariki, I., Elmansouri, O., & Badi, I. (2024). Optimizing construction and demolition waste management strategies in Libya: A FUCOM-EDAS multi-criteria decision-making approach. Journal of Green Economy and Low-Carbon Development, 3(4), 258–272. https://doi.org/10.56578/jgelcd030405

Althoey, F., Hakeem, I. Y., Hosen, M. A., Qaidi, S., Isleem, H. F., Hadidi, H., Shahapurkar, K., Ahmad, J., & Ali, E. (2022). Behavior of Concrete Reinforced with Date Palm Fibers. *Materials*, *15*(22), 7923. https://doi.org/10.3390/ma15227923

Alzard, M. H., El-Hassan, H., & El-Maaddawy, T. (2021). Environmental and economic life cycle assessment of recycled aggregates concrete in the United Arab Emirates. Sustainability, 13(18), 10348. https://doi.org/10.3390/su131810348

Bamaga, S. O. (2022). A review on the utilization of date palm fibers as inclusion in concrete and mortar. Fibers, 10(4), 35. https://doi.org/10.3390/fib10040035

Charef, R., Lu, W., & Hall, D. (2022). The transition to the circular economy of the construction industry: Insights into sustainable approaches to improve the understanding. Journal of Cleaner Production, 364, 132421. https://doi.org/10.1016/j.jclepro.2022.132421

Ghisellini, P., Ripa, M., & Ulgiati, S. (2018). Exploring environmental and economic costs and benefits of a circular economy approach to the construction and demolition sector: A literature review. Journal of Cleaner Production, 178, 618–643. https://doi.org/10.1016/j.jclepro.2017.11.207

Ginga, C. P., Ongpeng, J. M. C., & Daly, M. K. M. (2020). Circular economy on construction and demolition waste: A literature review on material recovery and production. Materials, 13(13), 2970. https://doi.org/10.3390/ma13132970

Hasheminezhad, A., King, D., Ceylan, H., & Kim, S. (2024). Comparative life cycle assessment of natural and recycled aggregate concrete: A review. Science of the Total Environment, 950, 175310. https://doi.org/10.1016/j.scitotenv.2024.175310



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International Organization for Standardization. (2006). Environmental management—Life cycle assessment—Principles and framework (ISO 14040:2006). https://www.iso.org/standard/37456.html

International Organization for Standardization. (2020). Sustainability in buildings and civil engineering works—Design for disassembly and adaptability—Principles, requirements and guidance (ISO 20887:2020). https://www.iso.org/standard/69370.html

Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. Resources, Conservation and Recycling, 127, 221–232. https://doi.org/10.1016/j.resconrec.2017.09.005

López Ruiz, L. A., Roca Ramón, X., & Gassó Domingo, S. (2020). The circular economy in the construction and demolition waste sector—A review and an integrative model approach. Journal of Cleaner Production, 248, 119238. https://doi.org/10.1016/j.jclepro.2019.119238

Nedeljković, M., Visser, J., Šavija, B., Valcke, S., & Schlangen, E. (2021). Use of fine recycled concrete aggregates in concrete: A critical review. Journal of Building Engineering, 38, 102196. https://doi.org/10.1016/j.jobe.2021.102196

Oluleye, B. I., Chan, D. W. M., Saka, A. B., & Olawumi, T. O. (2022). Circular economy research on building construction and demolition waste: A review of current trends and future research directions. Journal of Cleaner Production, 357, 131927. https://doi.org/10.1016/j.jclepro.2022.131927

Piccinali, A., Diotti, A., Plizzari, G., & Sorlini, S. (2022). Impact of recycled aggregate on the mechanical and environmental properties of concrete: A review. Materials, 15(5), 1818. https://doi.org/10.3390/ma15051818

Pomponi, F., & Moncaster, A. (2017). Circular economy for the built environment: A research framework. Journal of Cleaner Production, 143, 710–718. https://doi.org/10.1016/j.jclepro.2016.12.055

Pristerà, G., Tonini, D., Lamperti Tornaghi, M., Caro, D., & Sala, S. (2024). Taxonomy of design for deconstruction options to enable circular economy in buildings. Resources, Environment and Sustainability, 15, 100153. https://doi.org/10.1016/j.resenv.2024.100153

Purchase, C. K., Al Zulayq, D. M., O'Brien, B. T., Kowalewski, M. J., Berenjian, A., Tarighaleslami, A. H., & Seifan, M. (2022). Circular economy of construction and demolition waste: A literature review on lessons, challenges, and benefits. Materials, 15(1), 76. https://doi.org/10.3390/ma15010076

Shiboub, I., & Assaf, G. J. (2019). A system dynamic model for sustainable construction and demolition waste recycling in Libya. European Scientific Journal, 15(6), 191. https://doi.org/10.19044/esj.2019.v15n6p191

Soto-Paz, J., Arroyo, O., Torres-Guevara, L. E., Parra-Orobio, B. A., & Casallas-Ojeda, M. (2023). The circular economy in the construction and demolition waste management: A comparative analysis in emerging and developed countries. Journal of Building Engineering, 78, 107724. https://doi.org/10.1016/j.jobe.2023.107724

Zhang, Y., Luo, W., Wang, J., Wang, Y., Xu, Y., & Xiao, J. (2019). A review of life cycle assessment of recycled aggregate concrete. Construction and Building Materials, 209, 115–125. https://doi.org/10.1016/j.conbuildmat.2019.03.078



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