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Research Article

Integrating Circular Economy in Retrofit: Global Practices in Sustainable Construction

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ABSTRACT

The construction industry is among the most resource-intensive sectors globally, contributing approximately 39% of total carbon dioxide emissions. Retrofitting existing structures has emerged as a crucial pathway toward achieving sustainability goals. Integrating Circular Economy (CE) principles—such as material reuse, lifecycle assessment, and closed-loop design—into retrofit strategies can significantly enhance resource efficiency and environmental performance. Despite growing interest, the global application of CE in retrofitting remains inconsistent and underdeveloped across regions. This study presents a structured synthesis of global practices at the intersection of CE and sustainable retrofit strategies within construction engineering and project management. A systematic literature review was conducted using the PRISMA methodology across major academic databases, yielding 44 relevant studies and empirical case examples published between 2010 and 2024. Thematic coding was applied based on three dimensions: circularity potential, retrofit performance, and stakeholder engagement. Findings indicate that CE-informed retrofitting is gaining momentum, particularly through approaches such as modular construction, adaptive reuse, and material recovery. Enabling technologies like Building Information Modelling (BIM), digital twins, and lifecycle assessment tools, along with supportive governance frameworks, are identified as key enablers. However, challenges such as limited CE expertise, high upfront costs, inconsistent policy implementation, and inadequate secondary material databases continue to hinder widespread adoption. Regional comparisons reveal leadership in Europe and parts of Asia, while emerging innovations are observed in select Global South contexts. The study concludes that effective CE-based retrofitting requires the convergence of integrated project management, enabling technologies, and harmonized regulatory mechanisms. Future research should focus on developing standardized frameworks, quantifiable impact evaluation models, and comparative cross-regional analyses to accelerate global adoption.

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1. INTRODUCTION

The construction industry is one of the most resource-intensive in the world. It uses a lot of raw materials, energy, and water, and it is responsible for around 39% of the world's carbon dioxide (CO_2) emissions. Retrofitting old buildings and infrastructure has become an important way to reach net-zero carbon emissions and stop the damage to the environment. Retrofitting not only makes buildings last longer, but it also greatly improves how well they use energy and resources. But standard retrofit methods generally focus only on operating efficiency and don't take into account long-term environmental effects and material circularity (Myint & Shafique, 2024).

The idea of a Circular Economy (CE) has gotten a lot of attention around the world as a good alternative to the old "take-make-dispose" model. CE principles stress thinking about the whole life cycle of a product, reducing waste, making better use of resources, and reusing materials (Kirchherr *et al.*, 2023a).

When used in the built environment, CE gives us a whole means to rethink how we construct, maintain, and improve buildings. Using CE principles in retrofit plans helps keep carbon that is already in the building, helps get back valuable materials, and promotes long-term sustainability throughout the building's life. Even while this is possible, CE is still not fully established and is not being used consistently in retrofit operations around the world (Rahla *et al.*, 2021).

There is a big gap between the theoretical progress made in CE and how it is used in real-world retrofit projects. Many studies talk about CE in construction and sustainable retrofitting separately, but not many give a whole picture of how these two areas work together in real life. In addition, differences in legislation, readiness for new technologies, involvement of stakeholders, and ways of delivering projects have made it hard for circular retrofit solutions to be widely used (Foster, 2020).

The goal of this article is to look at and combine the best practices from around the world in the areas of circular economy and sustainable retrofit solutions in building engineering and project management. The paper's main goals are to: 1. Look at the current state of CE-integrated retrofit projects around the world; 2. Find successful frameworks, tools, and integration methods that are used to include CE principles in retrofit projects; and 3. Give construction engineers, project managers, and policymakers suggestions on how to make the planning, execution, and evaluation of sustainable retrofit projects better.

The main objectives of this study are to:

1. Assess the current global landscape of retrofit projects that integrate Circular Economy (CE) principles in construction engineering and project management.
2. Identify effective frameworks, tools, and integration approaches that facilitate the adoption of CE strategies in retrofitting practices.
3. Provide actionable recommendations for construction engineers, project managers, and policymakers to enhance the planning, execution, and evaluation of sustainable, CE-based retrofit initiatives (Fernandes *et al.*, 2021).

2. LITERATURE REVIEW

2.1 Circular Economy in the Built Environment

The Circular Economy (CE) is a way of thinking that tries to get rid of waste and get the most value out of resources by using them over and over again. CE wants to close material loops, lower the impact on the environment, and change the way buildings are produced and torn down in the built environment. The main ideas behind it are using closed-loop materials that are constantly cycled through reuse and recycling systems; designing for disassembly, which makes it easy to take apart and reuse building parts; and product-as-a-service, which replaces ownership with service-based access to products, extending lifecycle responsibility (Kirchherr *et al.*, 2023b)

There are now explicit models and frameworks for using CE in building. The Ellen MacArthur Foundation describes the ReSOLVE framework—Regenerate, Share, Optimise, Loop, Virtualise, and Exchange—as a way for businesses to put CE ideals into action. At the same time, Cradle-to-Cradle (C2C) accreditation looks at the environmental and health effects of materials on a product level and encourages the use of safe, recyclable parts in buildings (Iyer-Raniga, 2019). So, CE in construction extends beyond just cutting down on waste. It also looks at material health, circular design, and new ways to improve the supply chain.

In recent years, construction methods that are good for the environment, like modular construction, prefabricated parts, and adaptive reuse, have slowly become more popular. But these are still mostly limited to certain areas, such Western Europe and portions of Asia, and they haven't spread much over the world. Some of the problems are rules that make it hard to do things, not knowing how to design things in a circular way, and not having enough financial incentives to reuse things instead of building new ones (Parracho *et al.*, 2025).

2.2 Sustainable Retrofitting in Construction Engineering

Sustainable retrofitting means making changes to old buildings and infrastructure to make them better for the environment, use less energy, and be more resilient overall. It includes a wide range of actions, such as energy retrofits (such HVAC improvements and insulation), substantial renovations (big modifications that touch more than one building system), and reusing or replacing the facade to make it look better and work better while keeping the value of the materials (Wan *et al.*, 2022).

Retrofitting is an important aspect of global climate action, especially since more than half of the buildings that will be erected by 2050 are already existing (Bjelland *et al.*, 2024). A lot of these buildings are not very energy-efficient and are getting close to the end of their useful lives. Retrofitting is a long-term solution that keeps embodied carbon and cuts down on resource extraction, therefore it is better than tearing down and building new (Abu Dabous & Hosny, 2025).

Retrofitting is important all over the world because it fits with the United Nations Sustainable Development Goals (SDGs), especially SDG 11 (Sustainable Cities and Communities) and SDG 13 (Climate Action). Not only does retrofitting reduce the negative effects on the environment, it also makes buildings more resilient, improves the health of the people who live in them, and makes the economy more inclusive (Hauashdh *et al.*, 2024).

Lifecycle Assessment (LCA) and Building Energy Modelling

(BEM) are two important methods used to plan retrofits. LCA lets you look at the environmental effects of a structure over its whole life, which helps you make choices that maximise material reuse and cut down on emissions. BEM helps model and improve energy use throughout the planning phase and after the renovation. These tools are useful, but they don't usually provide circular metrics, which is a missed chance in CE-driven retrofit efforts (Fahlstedt *et al.*, 2024).

2.3 Linking Circular Economy and Retrofit Strategies

The combination of CE and sustainable retrofitting creates a strong foundation for getting the most environmental, social, and economic value out of building. Retrofitting, which is all about making old assets better and lasting longer, fits well with CE's focus on thinking about the whole lifecycle and saving resources (Moustafa *et al.*, 2025).

One important synergy is the goal of material efficiency, which is a main goal of CE. Retrofitting makes this easier by allowing the disassembly and reuse of materials like steel, masonry, and wood, which lowers the need for new materials. Reversible building design strategies and material passports make it even more likely that parts can be reused and redeployed during the life of a structure (Majumder *et al.*, 2025).

The circular retrofit hierarchy, which is based on the standard waste hierarchy, puts acts in this order of importance:

1. Avoid (avoid need for material replacement), 2. Reduce (minimise material intake), 3. Reuse (keep components in place or off-site), 4. Refurbish (extend lifespan through repair/upgrades), and 5. Recycle (turn materials into new goods) (Zhang *et al.*, 2022).

Projects that use this hierarchy are more likely to reach their targets of both carbon and material circularity. For instance, Dutch retrofitting projects have been able to reuse structural steel parts and concrete panels. Several cities in Scandinavia are now using databases of second-hand materials for public projects. But scalability is still hard, and it's often limited by a lack of digital infrastructure and market demand. A hierarchical model that ranks actions based on their impact on the environment and resources can be used to organise the use of circular economy (CE) principles in retrofit plans. Figure 1 shows that the circular retrofit hierarchy goes from the best strategy, which is to avoid using materials that aren't needed, to the worst option, which is still useful but not as good, which is recycling (Foster, 2020; Pineda-Martos *et al.*, 2025).

Figure 1. Circular Retrofit Hierarchy.

A visual representation of the circular retrofit hierarchy, illustrating the prioritized sequence of circular strategies: Avoid, Reduce, Reuse, Refurbish, and Recycle. The hierarchy emphasizes waste prevention and material efficiency as foundational principles in circular economy-based retrofit planning.

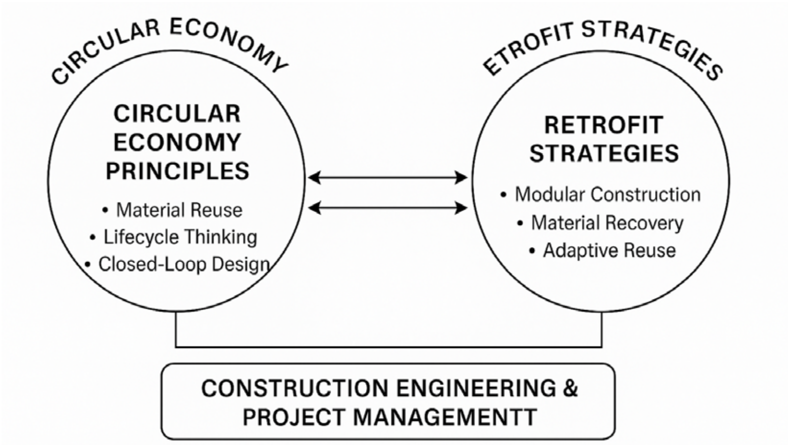

Figure 2. Interrelationship between Circular Economy (CE) principles and sustainable retrofit strategies.

This conceptual framework highlights how core Circular Economy principles material reuse, lifecycle thinking, and closed-loop design directly inform and enhance retrofit strategies such as modular construction, material recovery, and adaptive reuse. This integration is facilitated through construction engineering and project management processes that align project delivery with sustainability objectives.

2.4 Policy and Regulatory Drivers Across Regions

Policy frameworks help speed up the use of CE-informed retrofit methods. The EU Green Deal and the Circular Economy Action Plan have made buildings the main focus of climate strategy in Europe. The Level(s) framework gives us a common set of sustainable performance criteria, such as lifetime indicators that are important for CE and retrofitting. In the Netherlands and Denmark, national rules encourage deconstruction, reusing resources, and using digital tracking systems for building parts (Kirchherr *et al.*, 2023c).

China has been a leader in developing CE policies in Asia since the early 2000s. Its Circular Economy Promotion Law and later municipal pilot projects have made it easier to reuse materials while managing construction and demolition (C&D) waste. Japan and Singapore have also offered incentives for green retrofitting and modular construction. These are in line with circular ideas through urban redevelopment plans (Ogunmakinde, 2019).

Market-driven systems are the most common in North America. LEED and WELL are examples of voluntary certifications that include measures that are good for the environment, like adaptive reuse, good indoor air quality, and using materials that don't release carbon. But there is still a lack of regulatory support for CE. Cities like Vancouver and San Francisco are already requiring reviews of demolition and salvage, which other cities may follow (Abraham *et al.*, 2022).

The Global South is a mixed bag. While urban development and lack of infrastructure are important issues, retrofitting doesn't get much policy attention. However, pilot programs in countries like South Africa and Colombia show that CE-retrofit integration is possible, especially when international alliances and public-private cooperation are involved (Arku & Marais, 2021).

Across areas, public procurement is becoming an important tool. Governments can help shift the market by requiring bidders to include circular criteria and picking materials and parts that have less of an effect. Some incentive programs that can aid with retrofitting are tax credits, green building subsidies, and materials exchange platforms. However, they are not employed enough in many cases.

3. METHODOLOGY

3.1. Research Design

This study employed a systematic narrative review combined with comparative case analysis to explore the integration of Circular Economy (CE) principles in sustainable retrofit practices globally. A structured narrative review is especially effective for addressing interdisciplinary themes such as CE and sustainable retrofitting, as it allows for the synthesis of diverse policy frameworks, technologies, and practices. The review encompassed peer-reviewed academic literature, industry reports, and relevant grey literature to ensure comprehensive coverage of both theoretical insights and practical challenges.

To ensure the methodological rigor of the review, the following inclusion criteria were applied:

- Publications from 2010 to 2024
- English-language sources
- A focus on retrofitting or renovation projects that incorporate CE principles
- Empirical case studies, frameworks, or systematic reviews relevant to construction engineering or project management

Exclusion criteria included:

- Studies focused solely on new construction without retrofit components
- Publications lacking methodological transparency
- Articles unrelated to the built environment (e.g., CE applications limited to manufacturing)

This selection process aligns with best practices for systematic reviews, following the guidance provided by Adams (2024) and other contemporary sources.

3.2. Data Collection and Analysis

Data were sourced from leading academic databases including Scopus, ScienceDirect, and Web of Science using combinations of keywords such as "circular economy," "sustainable retrofit," "construction engineering," "building renovation," and "project management." Boolean operators (AND, OR) and database-specific filters were employed to refine search results by publication date, document type, and subject area.

The review followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) methodology, proceeding through four key stages: identification, screening, eligibility assessment, and inclusion (Folorunsho & Okyere, 2025). An initial pool of 562 documents was narrowed down to 44 studies deemed most relevant after abstract and full-text reviews.

NVivo software was used for thematic coding, enabling structured analysis of both deductive categories (e.g., CE strategies, retrofit types, and policy mechanisms) and inductively derived themes (e.g., stakeholder conflict, data infrastructure challenges). This dual coding approach facilitated nuanced pattern recognition and cross-regional comparison.

3.3. Analytical Framework

The selected studies and cases were assessed using an analytical framework structured around three key evaluation dimensions:

1. Circularity Potential: The degree to which retrofit strategies enable closed-loop systems, such as through material reuse or design for deconstruction.
2. Retrofit Performance: Improvements in energy efficiency, lifecycle cost reductions, and minimization of carbon emissions.
3. Stakeholder Engagement: The extent and effectiveness of collaboration among architects, engineers, contractors, policymakers, and end-users.

Additionally, each case was categorized based on:

- Geographic Region (e.g., Europe, Asia, Global South)
- Project Scale (building-level, district-level, or city-wide)
- Retrofit Depth (light, medium, or deep interventions)

4. RESULTS AND DISCUSSION

4.1. Categorization of Global Retrofit Strategies Applying CE

More and more, retrofit plans are using ideas from the circular economy (CE). However, the types and methods used depend a lot on the situation, the building's purpose, and the size of the project. One big difference is between retrofits for homes and retrofits for businesses. When it comes to residential projects, the main goals are to make homes more energy-efficient and comfortable. When it comes to commercial retrofits, the main goals are to save money on operating costs, meet building certification standards, and promote sustainability through branding (Besana & Tirelli, 2022).

Heritage and historic buildings are a special type of building that presents both obstacles and opportunity for circular retrofitting. To keep the integrity of the building while adding modern energy systems, new design ideas are needed, like internal insulation retrofits and systems that don't require any work on the building. Modern infrastructure, especially from the development boom after World War II, is more flexible for thorough retrofits. This means that modular interventions and structural changes are generally possible. Table 1 groups global retrofit strategies by building type, geographical example, circular approaches used, and the obstacles and rewards that come from each. This helps us understand how circular economy ideas are used in diverse retrofit situations (Kakouei *et al.*, 2025).

Table 1. Typology of Global Retrofit Strategies

Typology	Example Countries	Common CE Strategies	Challenges	Benefits
Residential	Netherlands	Material recovery Modular retrofitting Adaptive Reuse	Limitations on Structural Changes Occupant Disruption	Lower energy bills Improved indoor comfort Preservation of community character
Commercial	France Japan	Off-site Construction Adaptive Reuse Façade Reuse	Regulatory Constraints Cost Premiums	Operational savings Enhanced property value Brand reputation
Heritage	Italy Germany	Adaptive Reuse Selective Disassembly	Preservation of Cultural Value Reduce Embodied Carbon	Cultural preservation Reduced demolition waste Tourism appeal
Modern Infrastructure	Singapore Denmark	Modular Retrofitting Façade Reuse Energy Retrofits	Stringent Environmental Targets Large-Scale Construction Impact	High-performance buildings Scalable impact Meeting climate targets

Table 1. Different types of global retrofit strategies. A look at the several types of retrofits—residential, commercial, heritage, and new infrastructure—comparing example countries, common circular economy (CE) tactics, problems with implementation, and the benefits of each strategy.

CE-based retrofits are all about recovering and reusing materials. Reusing bricks, wood, steel, and glass from buildings that have been torn down is one example of success. In Denmark, a program to adapt municipal buildings saved more than 80% of the bricks so they could be used again in new facades. In the UK, reclaimed wood is often used again in residential constructions for structural or ornamental purposes. Even with these improvements, the reuse of materials is limited by worries about quality, a lack of standardisation, and the fact that they are not always available on the market (Balasbaneh *et al.*, 2025).

Modular retrofitting, which uses pre-made panels and assemblies, is becoming more popular as a circular solution. The Energiesprong project in the Netherlands shows how using prefabricated roofs and façades can cut down on building time, waste, and the need to replace or upgrade parts over time. In the same way, off-site construction helps circularity by making it easier to regulate materials, simplifying logistics, and causing less disruption on site (Zanni *et al.*, 2021).

Another popular method is adaptive reuse, which changes the purpose of whole buildings (for example, turning warehouses into offices or schools into homes). These projects usually keep much of the building's envelope and structural system, which cuts down on embodied carbon and the need for new materials. Adaptive reuse has become an important model for urban CE-based retrofitting, especially in places with a lot of people and not much greenfield area (Shahi *et al.*, 2020).

4.2 Project Management Considerations

Adding circular concepts to retrofit projects means that we need to reconsider how we manage projects in the past. One major change is that lifetime costing (LCC) is now the main way to make decisions instead of upfront capital cost. LCC captures long-term savings through lower disposal costs, less material use, and more energy efficiency, which is more in line with CE goals (Kambanou, 2020).

Another important thing is getting all the stakeholders on the same page. Many different people are involved in retrofitting projects, including architects, engineers, building owners, and city officials, each with their own set of goals. To balance expectations, handle trade-offs, and make sure that everyone understands and follows CE principles throughout the project lifecycle, early and ongoing involvement is necessary (Motalebi *et al.*, 2025).

Some people don't want to conduct circular retrofitting because they think it is too risky, especially when employing old or uncommon materials. Risk mitigation approaches need to deal with quality assurance, the unpredictability of the supply chain, and the need for design flexibility. These include pilot testing, programs to certify suppliers, and making sure that there are backup plans in place for design changes that may need to be made due of circular sourcing constraints (Jia *et al.*, 2024).

CE also has a direct effect on how projects are planned and when they will happen. For example, it could take longer to find reused parts, so it's crucial to plan ahead and be flexible. Also, supply chain integration needs to include reverse logistics, which means taking things apart, storing them, and making them available on the secondary market. Digital tools like material passports and product monitoring platforms can help make these tasks easier, but not many people utilise them yet (Diaz *et al.*, 2021).

4.3. Enablers and Barriers to CE-Based Retrofitting

4.3.1. Enablers

Digital technology are one of the most crucial elements that have made circular retrofitting possible. Digital twins and Building Information Modelling (BIM) let individuals examine, simulate, and keep an eye on retrofit projects in great detail. This helps people make decisions based on data. These tools can help you detect problems, simulate energy use, and keep track of materials, all of which are vital for generating the greatest circular results (Thirumal *et al.*, 2024).

One example of a circular design tool that delivers organised advise on how to employ CE strategies is the Ellen MacArthur Foundation's ReSOLVE framework. "Loop" (reusing and recycling resources), "Optimise" (making things work better), and "Exchange" (switching to renewable materials and technology) are some of these. One Click LCA and SimaPro are two examples of Lifecycle Assessment (LCA) software that may help you choose materials and see how they effect the environment by giving you data that you can measure (Lewandowski, 2016).

Strong governance frameworks and regulatory regimes that support them are other crucial variables that make this possible. Amsterdam and Helsinki are two cities that want to be both sustainable and part of the circular economy. They tend to have more CE retrofits that function together. Public mandates, procurement rules, and the power of local governments make this ecosystem viable (Cuomo *et al.*, 2020).

4.3.2. Barriers

Even while things are moving in the right direction, there are still several problems that make it hard for CE-based retrofitting to be used by everyone. One big problem is that construction workers don't know enough about CE. Most people who work in the sector know how to use linear design and project delivery methods, but not many know how to use circular strategies well (Shooshtarian *et al.*, 2025).

Another thing that keeps people from doing it is the high upfront expenditures. CE retrofitting usually saves money in the long run, but it costs more to change designs, use non-standard materials, and take things apart than it does to use traditional procedures. Clients might not want to use circular approaches if there aren't clear business models or incentives.

The lack of trustworthy material databases that list accessible reused materials, where they are, their specifications, and their compliance status makes it hard to plan and keep quality control. Because of this, contractors often choose new materials because they are more predictable and legally safe (Boskovic & Cullen, 2025).

Finally, a big problem is that policies are not being put into place in a consistent way. In a lot of places, circular construction rules are new or not very well enforced. Different construction laws, waste rules, and incentives for green building might cause misunderstanding or dispute, which makes it harder for people to adopt circular practices. A SWOT analysis was made to bring together the internal and external elements that affect the use of circular economy (CE) principles in retrofitting. This framework includes both the factors that help and the factors that make it harder to adopt CE in projects, policies, and markets (Oke *et al.*, 2025).

Figure 3. SWOT Matrix of Enablers and Barriers in CE-Based Retrofitting.

STRENGTHS (Internal, Positive Factors)	**WEAKNESSES (Internal, Negative Factors)**
Digital tools (BIM, Digital Twins) for material tracking and simulation	Lack of CE expertise among construction professionals
Lifecycle costing (LCC) supporting long-term savings	Limited availability of standardized material databases
Circular design frameworks (e.g., ReSOLVE) guiding CE implementation	Higher upfront costs for CE-based retrofit methods
Stakeholder alignment improving communication across the project lifecycle	Limited experience with circular procurement and logistics
OPPORTUNITIES (External, Positive Factors)	**THREATS (External, Negative Factors)**
Government incentives and circular public procurement policies	Fragmented or poorly enforced CE-related regulations
Expanding secondary material and salvage markets	Concerns about quality assurance for reused components
International funding and partnerships (esp. in Global South)	Client resistance to reused or unfamiliar materials
Rising demand for green building certifications and low-carbon retrofits	Tight project timelines conflict with extended CE sourcing needs

This matrix gives a strategic look at the pros and cons, chances, and dangers of using circular economy ideas in sustainable retrofit projects. It separates internal factors (such digital tools and gaps in knowledge) from external factors (like policy support and inconsistent regulations), giving us a better understanding of both the things that help and the things that make CE-based project delivery harder.

4.4 Regional Comparison and Best Practice

4.4.1. Europe

The European Union's Green Deal, Circular Economy Action Plan, and national programs have all helped Europe become the best place in the world to use CE ideas for retrofitting. The Netherlands was the first country to adopt city material banks and rules for circular construction. The "Superlocal" project is an example of a whole building destruction that uses parts from other buildings. With the support of the government, Denmark has started employing digital systems to keep track of building materials and has offered financial incentives for modular retrofits.

4.4.2. Asia

Asia has a combination of fast-growing cities and new ways of doing things. Japan's architectural culture, which focusses on durability, encourages circularity by using lasting materials and making things that don't need to be replaced often. Singapore has made it necessary for public housing projects to use integrated planning tools, set green retrofitting goals, and follow circular material requirements. China's CE laws have encouraged the reuse of construction and demolition debris, however enforcement and uniformity differ from region to region (Herrador *et al.*, 2023).

4.4.3. Africa and Latin America

In the Global South, grassroots groups and international alliances are starting to use circular retrofitting. Low-cost, low-tech solutions are being used even when institutional support is weaker. In South Africa, urban upgrading initiatives use materials that have already been used and create jobs at the same time. Colombia's urban retrofitting pilots combine improvements to informal housing with cyclical resource flows, with help from NGOs and worldwide funding agencies. Even though there are problems with the system, these instances show that circular tactics can work in different places (Visagie & Turok, 2020).

This global synthesis shows that CE-retrofit integration is becoming more common, but it is still very unequal. Best practices are frequently specific to a certain area and depend a lot on policy alignment, digital preparedness, and stakeholder ability. Still, a clear path is starting to take shape: retrofit plans based on circular principles can lead to urban change that is more environmentally friendly, resource-efficient, and socially inclusive.

4.5. Policy Implementation Gaps and Regional Contrasts

Despite strong conceptual frameworks for CE integration, actual implementation varies widely. In Europe, over 70% of countries have adopted national strategies or legal instruments supporting circular construction, backed by EU-wide directives such as the Green Deal and the Circular Economy Action Plan. For example, the Netherlands mandates material passports and deconstruction audits for public projects, while Denmark links subsidies to circular performance indicators.

In contrast, fewer than 20% of countries in Africa and Latin America have formal CE-aligned construction policies. Where they exist, such as in South Africa and Colombia, initiatives are often donor-driven or pilot-scale. For instance, South Africa's circular retrofitting programs have reached fewer than 5% of urban settlements, and Colombia's housing upgrade pilots remain localized, without national policy uptake.

Barriers in the Global South include limited institutional capacity, inconsistent regulatory enforcement, and a lack of localized standards for reused materials. Moreover, public procurement rarely includes circular criteria, in contrast to developed nations where government tenders increasingly require lifecycle and circularity assessments.

This policy gap not only restricts large-scale retrofitting but also limits private sector confidence and investment in CE-based models. Bridging this divide will require region-specific frameworks, capacity-building programs, and mechanisms for knowledge transfer between regions.

5. CONCLUSION

This review has put together information from around the world about how to use circular economy (CE) ideas and sustainable retrofit strategies in construction engineering and project management. The results show that CE has a significant and growing chance of completely changing how retrofitting is thought about, done, and judged. Retrofitting is already an important part of sustainable development, but it can have an even bigger impact when it follows circular concepts like reusing materials, designing for disassembly, and thinking about the whole lifecycle. Instead of seeing retrofits as separate technical improvements, CE sees them as chances to improve the use of resources throughout the system and create value over time.

One important thing that this study shows is that project management needs to change to meet the cyclical, adaptable, and collaborative nature of circular retrofitting. This includes changes in how plans are made, how stakeholders work together, how goods are bought, and how performance is measured. We need to include indicators like lifespan carbon, circularity potential, and materials traceability to traditional linear models that only look at cost and time efficiency. Digital tools like BIM, digital twins, and LCA software can help, but they need to be integrated into project workflows by people who know how to do it.

For CE-based retrofitting to work, supportive policies, digital technology, and multi-stakeholder governance frameworks must all work together. Best practices in Europe and some areas of Asia show how important it is to have policies that bring together legislative requirements, financial incentives, and changes to public procurement. But there are also differences between regions, especially in the Global South, where low institutional capacity, funding, and access to circular materials and technology make it hard to put the ideas into practice.

There are some problems with this study. There is a lot of literature on this topic, however there may be some prejudice because most of the case studies are from high-income countries. Also, a lot of the data is based on ideas or stories, and there isn't much quantitative analysis of effects across different places (Lawal *et al.*, 2025).

FUTURE STUDIES

Future research should focus on creating standardised circular retrofit frameworks, empirically validated impact evaluation methods, and cross-country studies that compare scalability, equity, and cost-effectiveness. These are all important for moving the topic forward. Adding these results to engineering courses and professional training will help spread CE principles to retrofit projects around the world even further (Lawal *et al.*, 2025).

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