International Journal of Education, Vocational and Social Science
https://e-journal.citakonsulfindo.or.id/index.php/IJEVSS
E-ISSN : 2963 4954
IJEVSS

Engineering A Circular Economy Model For Construction Excavation Waste Management In SABODAM: A Systematic Literature Review

Eko Prasetyo
Doctoral Program in Engineering Management, National Institute of Technology, Malang, Indonesia
Lalu Mulyadi
Doctoral Program in Engineering Management, National Institute of Technology, Malang, Indonesia
Fourry Handoko
Doctoral Program in Engineering Management, National Institute of Technology, Malang, Indonesia
Nanta Sigit
Doctoral Program in Engineering Management, National Institute of Technology, Malang, Indonesia

Corresponding Author: soetiknoprasetyo9@gmail.com

Abstract

The construction industry is one of the largest consumers of natural resources and generators of waste worldwide, with excavation activities producing substantial quantities of soil, rock, and sediment materials that are often disposed of without further utilization. The increasing demand for sustainable infrastructure development has intensified the need for innovative approaches that improve resource efficiency while reducing environmental impacts. Circular Economy (CE) and Green Innovation have emerged as promising strategies for transforming construction waste into valuable secondary resources. However, limited research has specifically addressed the integration of CE, Green Innovation, Life Cycle Assessment (LCA), and Life Cycle Costing (LCC) within the context of SABODAM construction excavation waste management.

This study aims to systematically review the existing literature on circular economy implementation in construction excavation waste management and identify opportunities for developing a sustainable framework applicable to SABODAM infrastructure projects. A Systematic

Copyright at authors some right reserved this work is licensed under a Creative Commons Attribution-Share Alike 4.0 International License

Literature Review (SLR) was conducted following the PRISMA 2020 guidelines using peer-reviewed articles published between 2015 and 2025. The review synthesizes evidence related to circular construction practices, resource recovery, recycled aggregates, environmental assessment, economic evaluation, and green innovation.

The findings reveal that integrating CE, Green Innovation, LCA, and LCC can significantly enhance resource circularity, environmental performance, and economic efficiency. The study proposes an integrated CE–Green Innovation–LCA–LCC framework to support sustainable and resilient SABODAM infrastructure development.

Keywords: Circular Economy, Green Innovation, Construction Excavation Waste, SABODAM, Life Cycle Assessment, Life Cycle Costing, Systematic Literature Review.

INTRODUCTION

The construction industry plays a fundamental role in economic growth, infrastructure development, and social progress worldwide. However, it is also recognized as one of the most resource-intensive sectors, accounting for approximately 50% of global raw material consumption and generating a substantial proportion of solid waste and greenhouse gas emissions. Construction and demolition waste (CDW) has become one of the fastest-growing waste streams globally due to rapid urbanization, increasing infrastructure investment, and expanding construction activities. Consequently, the industry faces growing pressure to transition toward more sustainable and resource-efficient practices that can simultaneously support economic development and environmental protection (Geissdoerfer et al., 2017; Kirchherr et al., 2017; Purchase et al., 2022).

Among the various waste streams generated by construction activities, excavation waste represents one of the largest yet least utilized material categories. Excavation operations associated with earthworks, foundations, transportation infrastructure, hydraulic structures, and disaster mitigation projects generate significant quantities of soil, sediment, rock fragments, and gravel materials. In many developing countries, including Indonesia, these materials are commonly transported to disposal sites or stockpiled without further utilization, despite their considerable potential as secondary construction resources. Such practices result in increased environmental burdens, inefficient resource utilization, and additional economic costs associated with transportation and disposal activities (Illankoon & Vithanage, 2023; Papamichael & Chrysanthopoulos, 2023; Gherman et al., 2023).

Copyright at authors some right reserved this work is licensed under a Creative Commons Attribution-Share Alike 4.0 International License

The concept of the Circular Economy (CE) has emerged as a promising solution to address the challenges of waste generation and resource depletion within the construction sector. CE promotes the transition from a linear economic model toward a regenerative system that prioritizes waste prevention, material reuse, recycling, resource recovery, and value retention throughout the life cycle of materials and products. By treating waste as a valuable resource rather than a disposal problem, CE has the potential to significantly reduce environmental impacts while simultaneously generating economic and social benefits. Numerous studies have demonstrated that circular construction practices can reduce virgin material extraction, minimize landfill dependency, lower greenhouse gas emissions, and improve overall resource productivity (Geissdoerfer et al., 2017; Adams et al., 2017; Ossio et al., 2023).

The successful implementation of circular economy principles in the construction industry increasingly depends on the adoption of green innovation. Green innovation refers to the development and application of new technologies, processes, organizational practices, and business models that contribute to environmental sustainability while maintaining economic competitiveness. Within the context of construction and infrastructure development, green innovation facilitates the adoption of resource-efficient technologies, advanced recycling systems, digital material tracking, low-carbon construction methods, and sustainable waste management practices. Recent studies indicate that green innovation serves as a critical enabler of circular economy implementation because it enhances material recovery efficiency, improves environmental performance, and supports the creation of sustainable value chains throughout construction projects (Chen et al., 2022; Dangelico et al., 2017; Singh et al., 2024).

The integration of circular economy principles and green innovation is particularly important for infrastructure projects that involve substantial earthworks and material consumption. Innovations such as mobile crushing technologies, digital waste management platforms, Building Information Modeling (BIM), artificial intelligence-based material optimization, and life cycle assessment tools have significantly improved the feasibility of transforming excavation waste into reusable construction materials. These technologies not only reduce environmental impacts but also create new opportunities for cost savings and resource efficiency. Consequently, green innovation has become a strategic mechanism for accelerating the transition toward sustainable and circular infrastructure systems (Akanbi et al., 2018; Liu et al., 2021; Swarnakar et al., 2024).

In Indonesia, the importance of sustainable excavation waste management has become increasingly evident in the development of disaster mitigation infrastructure. One notable

Copyright at authors some right reserved this work is licensed under a Creative Commons Attribution-Share Alike 4.0 International License

example is the construction of SABODAM (Sabo Dam) systems, which are designed to control sediment transport, debris flows, and erosion in mountainous and disaster-prone regions. SABODAM structures play a critical role in protecting downstream communities and infrastructure from sediment-related hazards, particularly in volcanic and post-disaster environments. However, the construction of SABODAM facilities generates substantial quantities of excavation materials that are often underutilized despite their potential for reuse as aggregates, embankment materials, riprap, and structural fill. This situation presents a significant opportunity for implementing circular economy and green innovation strategies within disaster-resilient infrastructure development (Chen & Lee, 2015; Purchase et al., 2022; Soto-Paz et al., 2023).

The Province of Central Sulawesi provides a particularly relevant context for investigating this issue. Following the devastating earthquake, tsunami, and liquefaction events of 2018, the Indonesian government accelerated the development of disaster mitigation infrastructure, including numerous SABODAM projects managed by the River Basin Organization (Balai Wilayah Sungai). These projects generated substantial quantities of excavation waste while simultaneously requiring large volumes of construction materials. Such conditions create a unique opportunity to implement circular resource management strategies by converting excavation waste into valuable construction resources for use within the same project. This approach has the potential to reduce environmental impacts, improve resource efficiency, and lower overall project costs (BNPB, 2023; BWS Sulawesi III, 2023; Marrucci et al., 2025).

Although circular economy implementation in construction has received increasing attention over the last decade, existing research remains concentrated on buildings, urban development, and transportation infrastructure. Studies specifically examining excavation waste management in hydraulic and disaster mitigation infrastructure are still limited. Furthermore, most previous studies focus on individual dimensions such as technical performance, environmental impacts, or economic feasibility rather than integrating these aspects into a comprehensive decision-support framework. The lack of integrated approaches represents a significant gap in both the circular economy and sustainable infrastructure literature (Purchase et al., 2022; Ossio et al., 2023; Swarnakar et al., 2024).

Similarly, research investigating the relationship between circular economy and green innovation in the context of excavation waste management remains relatively scarce. Existing studies generally examine green innovation as an organizational or technological capability without explicitly addressing its role in facilitating material circularity within hydraulic infrastructure projects. Consequently, there is limited understanding of how green innovation can

Copyright at authors some right reserved this work is licensed under a Creative Commons Attribution-Share Alike 4.0 International License

support the development of circular economy models for excavation waste management while simultaneously improving environmental and economic performance in disaster mitigation infrastructure (Chen et al., 2022; Singh et al., 2024; Hasibuan et al., 2025).

To address these research gaps, this study conducts a systematic literature review entitled "Engineering a Circular Economy Model for Construction Excavation Waste Management in SABODAM: A Systematic Literature Review." The review aims to synthesize current knowledge regarding circular economy implementation, green innovation, excavation waste management, recycled aggregate utilization, Life Cycle Assessment (LCA), and Life Cycle Costing (LCC) within construction and infrastructure sectors. Through a rigorous PRISMA 2020 methodology, this study seeks to identify critical success factors, implementation barriers, technological opportunities, and sustainability outcomes associated with circular excavation waste management systems. The findings are expected to contribute to the development of an integrated CE–Green Innovation–LCA–LCC framework that can support sustainable and resilient SABODAM infrastructure development in Indonesia and other developing countries (Page et al., 2021; Purchase et al., 2022; Swarnakar et al., 2024).

LITERATURE REVIEW

Circular Economy Theory

The Circular Economy (CE) has emerged as one of the most influential sustainability paradigms for addressing environmental degradation, resource scarcity, and increasing waste generation. Unlike the traditional linear economic model based on the "take–make–dispose" principle, CE promotes the continuous circulation of materials, products, and resources through strategies such as reduction, reuse, recycling, remanufacturing, and recovery. The ultimate objective is to maintain the highest possible value of resources within the economic system while minimizing waste generation and environmental impacts (Geissdoerfer et al., 2017; Kirchherr et al., 2017).

The theoretical foundation of CE is strongly associated with industrial ecology, cradle-to-cradle design, performance economy, regenerative design, and sustainable resource management. These concepts collectively emphasize the transformation of waste into valuable resources and the establishment of closed-loop material cycles. Recent studies have demonstrated that CE contributes significantly to sustainable development by reducing dependence on virgin materials, lowering greenhouse gas emissions, and enhancing economic resilience through resource efficiency (Saidani et al., 2020; Purchase et al., 2022).

Copyright at authors some right reserved this work is licensed under a Creative Commons Attribution-Share Alike 4.0 International License

The construction sector has become one of the most important domains for CE implementation because of its substantial consumption of natural resources and generation of construction and demolition waste (CDW). Researchers have increasingly recognized CE as a transformative framework capable of improving material productivity and supporting sustainable infrastructure development. The transition toward circular construction requires systemic changes in design, procurement, construction processes, maintenance practices, and end-of-life management strategies (Adams et al., 2017; Ossio et al., 2023).

Recent studies emphasize that digital technologies such as Building Information Modeling (BIM), digital material passports, blockchain systems, and artificial intelligence are becoming critical enablers of circularity within the construction sector. These technologies facilitate material traceability, waste minimization, resource optimization, and circular decision-making throughout infrastructure life cycles (Hasibuan et al., 2025; Swarnakar et al., 2024).

Construction and Excavation Waste Management

Construction and demolition waste has become a major environmental challenge worldwide due to rapid urbanization, population growth, and extensive infrastructure development. The construction industry is estimated to generate one of the largest waste streams globally, accounting for a significant proportion of municipal and industrial solid waste. Improper waste management practices contribute to landfill expansion, environmental pollution, and depletion of natural resources (Purchase et al., 2022; Soto-Paz et al., 2023).

Among the various categories of CDW, excavation waste represents one of the largest fractions generated during infrastructure development projects. Excavation activities associated with foundations, tunnels, hydraulic structures, roads, and earthworks produce substantial quantities of soil, rock fragments, sediment, and gravel materials. Despite their significant reuse potential, these materials are frequently disposed of in spoil areas or landfills, resulting in unnecessary environmental and economic losses (Papamichael & Chrysanthopoulos, 2023; Gherman et al., 2023).

Modern waste management frameworks increasingly prioritize prevention, reduction, reuse, recycling, and recovery over disposal. This hierarchy aligns closely with CE principles and encourages the transformation of waste materials into secondary resources. Studies indicate that effective waste management systems require technological innovation, stakeholder engagement, supportive regulations, and economic incentives to facilitate the adoption of sustainable practices throughout the construction industry (Liu et al., 2021; Oluleye et al., 2022).

Copyright at authors some right reserved this work is licensed under a Creative Commons Attribution-Share Alike 4.0 International License

The integration of circular economy principles into excavation waste management offers significant opportunities to reduce landfill dependency and improve resource efficiency. Excavated soil and rock materials can be processed into construction aggregates, embankment materials, riprap, and backfill resources, thereby extending material life cycles and reducing demand for virgin resources. Such practices have become increasingly important within sustainable infrastructure development frameworks (Purchase et al., 2022; Hasibuan et al., 2025).

Recycled Aggregates and Resource Recovery

Resource recovery through recycled aggregate production represents one of the most established circular economy strategies within the construction sector. Recycled aggregates are commonly produced from construction and demolition waste, including concrete debris, excavation materials, masonry waste, and rock fragments. Their utilization reduces the extraction of natural aggregates while simultaneously diverting waste from landfills (Akhtar & Sarmah, 2018; Purchase et al., 2022).

Numerous studies have confirmed the technical feasibility of recycled aggregates for applications such as road construction, embankments, pavement layers, retaining structures, and concrete production. Advances in crushing, screening, washing, and beneficiation technologies have substantially improved the quality and performance of recycled materials, enabling broader implementation in infrastructure projects (Alexandridou et al., 2018; Soto-Paz et al., 2023).

Although recycled aggregates provide substantial environmental benefits, several challenges remain regarding their physical and mechanical properties. Compared with natural aggregates, recycled materials often exhibit higher porosity, greater water absorption, and increased variability. However, recent research demonstrates that appropriate quality control measures and advanced processing techniques can significantly improve aggregate performance and compliance with engineering standards (Purchase et al., 2022; Swarnakar et al., 2024).

From a circular economy perspective, recycled aggregate utilization contributes directly to resource conservation and environmental sustainability. The substitution of virgin aggregates with recycled materials reduces quarrying activities, decreases transportation requirements, and lowers greenhouse gas emissions associated with material extraction and processing (Cristóbal García et al., 2024; Purchase et al., 2022).

Life Cycle Assessment in Circular Construction

Life Cycle Assessment (LCA) is widely recognized as the most comprehensive methodology

Copyright at authors some right reserved this work is licensed under a Creative Commons Attribution-Share Alike 4.0 International License

for evaluating the environmental performance of products, materials, and infrastructure systems throughout their life cycle. Standardized under ISO 14040 and ISO 14044, LCA quantifies environmental impacts associated with resource extraction, manufacturing, transportation, construction, operation, maintenance, and end-of-life management (Finnveden et al., 2009; Hauschild et al., 2018).

Within circular construction research, LCA has become a fundamental decision-support tool for comparing alternative waste management and resource recovery strategies. Through the assessment of environmental impact categories such as climate change, energy consumption, resource depletion, eutrophication, and acidification, LCA enables the identification of environmentally preferable solutions (Purchase et al., 2022; Soto-Paz et al., 2023).

Numerous studies have demonstrated that recycled construction materials generally exhibit lower environmental impacts than virgin materials. Significant reductions have been reported in greenhouse gas emissions, energy demand, and raw material extraction when recycled aggregates are utilized in place of natural aggregates. Nevertheless, the environmental benefits are highly dependent on transportation distances, energy sources, recycling technologies, and local conditions (Cristóbal García et al., 2024; Swarnakar et al., 2024).

Recent research increasingly integrates CE principles into LCA frameworks to evaluate the environmental benefits generated by circular strategies such as reuse, recycling, and material recovery. This integration has strengthened the role of LCA as a critical analytical tool for sustainable infrastructure planning and decision-making (Hasibuan et al., 2025; Purchase et al., 2022).

Life Cycle Costing and Economic Evaluation

While environmental performance is essential for sustainable construction, economic feasibility remains a critical determinant of circular economy implementation. Life Cycle Costing (LCC) provides a comprehensive framework for assessing the total costs associated with materials, technologies, and infrastructure systems throughout their life cycles. Unlike conventional cost analysis methods, LCC incorporates capital costs, operational expenditures, maintenance costs, replacement expenses, disposal costs, and environmental externalities (Woodward, 1997; ISO 15686-5, 2017).

The application of LCC within circular construction has increased substantially during the last decade. Studies indicate that circular economy strategies often provide significant long-term economic benefits despite potentially higher initial investments. These benefits arise from

Copyright at authors some right reserved this work is licensed under a Creative Commons Attribution-Share Alike 4.0 International License

reduced material procurement costs, avoided landfill charges, lower transportation expenditures, and improved resource productivity (Giorgi et al., 2020; Cristóbal García et al., 2024).

The integration of LCA and LCC has become increasingly common in sustainability assessments because it enables simultaneous evaluation of environmental and economic performance. This integrated approach supports more balanced decision-making and facilitates the identification of solutions that maximize sustainability outcomes while maintaining economic viability (Purchase et al., 2022; Swarnakar et al., 2024).

Recent literature highlights the importance of adopting integrated CE-LCA-LCC frameworks to evaluate circular construction projects comprehensively. Such frameworks provide decision-makers with a robust basis for comparing conventional and circular alternatives across multiple sustainability dimensions (Hasibuan et al., 2025; Cristóbal García et al., 2024).

Circular Economy in Hydraulic and Disaster Mitigation Infrastructure

The implementation of circular economy principles within hydraulic and disaster mitigation infrastructure has received increasing attention due to growing concerns regarding climate resilience, sustainable resource management, and environmental protection. Infrastructure systems such as dams, levees, sediment control structures, and SABODAM facilities often involve extensive earthworks and generate substantial quantities of excavation materials that can potentially be reused within the project lifecycle (Soto-Paz et al., 2023; Swarnakar et al., 2024).

Hydraulic infrastructure projects require significant volumes of aggregates, riprap, embankment materials, and erosion-control resources. Circular economy strategies offer opportunities to recover and reuse excavation waste generated during construction activities, thereby reducing dependence on virgin materials while minimizing environmental impacts associated with waste disposal and transportation (Cristóbal García et al., 2024; Purchase et al., 2022).

Despite growing interest in circular infrastructure development, existing research remains heavily concentrated on buildings, urban infrastructure, and road construction projects. Studies specifically addressing excavation waste management in sediment-control and disaster-mitigation infrastructure remain extremely limited. Consequently, substantial knowledge gaps persist regarding the implementation of circular economy strategies within SABODAM and similar hydraulic infrastructure systems (Hasibuan et al., 2025; Bhavsar & Sridharan, 2025).

Copyright at authors some right reserved this work is licensed under a Creative Commons Attribution-Share Alike 4.0 International License

Research Gap

The existing literature demonstrates significant progress in the development of circular economy frameworks, construction waste management strategies, recycled aggregate technologies, and sustainability assessment methodologies. Numerous studies have explored circular economy implementation within construction and demolition waste management, while others have investigated environmental and economic performance through LCA and LCC analyses. However, the majority of these studies focus on buildings, urban development, and transportation infrastructure (Purchase et al., 2022; Soto-Paz et al., 2023).

Current research rarely addresses excavation waste management in hydraulic and disaster mitigation infrastructure, particularly within SABODAM construction projects. Furthermore, many studies evaluate technical, environmental, or economic dimensions separately rather than integrating them into a unified analytical framework. As a result, there remains a lack of comprehensive approaches capable of simultaneously addressing material circularity, environmental sustainability, and economic feasibility within excavation waste management systems (Swarnakar et al., 2024; Hasibuan et al., 2025).

The absence of an integrated Circular Economy–Life Cycle Assessment–Life Cycle Costing (CE-LCA-LCC) framework specifically designed for SABODAM construction excavation waste management represents a significant theoretical and practical gap. Addressing this gap is essential for supporting sustainable infrastructure development, improving resource efficiency, and enhancing disaster resilience in developing countries. Therefore, this systematic literature review seeks to synthesize existing knowledge and establish the foundation for an engineering-based CE-LCA-LCC model tailored to SABODAM infrastructure projects (Purchase et al., 2022; Bhavsar & Sridharan, 2025).

METHODOLOGY

Research Design

This study employs a Systematic Literature Review (SLR) approach based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines developed by Page et al. (2021). This approach was selected because it provides a systematic, transparent, reproducible, and scientifically rigorous procedure for identifying, selecting, critically evaluating,

Copyright at authors some right reserved this work is licensed under a Creative Commons Attribution-Share Alike 4.0 International License

and synthesizing evidence from previous studies. The adoption of PRISMA 2020 enables researchers to minimize literature selection bias while enhancing the reliability, validity, and credibility of the findings.

This review focuses on the development of a circular economy model for SABODAM construction excavation waste management by integrating the concepts of Circular Economy (CE), Construction and Demolition Waste Management (CDW), Life Cycle Assessment (LCA), and Life Cycle Costing (LCC). The scope of the review is limited to scientific journal articles published between January 2015 and December 2025 to ensure that the analyzed evidence reflects the most recent developments in sustainable construction and circular economy practices.

Literature Search Strategy

The literature search was conducted systematically across several internationally recognized scientific databases indexed by Scopus. The selection of databases was intended to achieve comprehensive literature coverage while minimizing the risk of overlooking relevant studies. The databases used in this review are presented in Table 3.1.

Table 3.1 Literature Search Databases

Database	Rationale for Selection
Scopus	The largest multidisciplinary database with extensive international journal coverage
ScienceDirect	Primary source of Elsevier publications in construction and environmental fields
Web of Science Core Collection	Used to verify publication quality and completeness
SpringerLink	Provides extensive literature in civil engineering and sustainability
MDPI	Offers recent publications in sustainability and circular economy research

The search was performed using a combination of keywords developed from the research objectives and the systematic review recommendations proposed by Kitchenham and Charters (2007). The primary keywords included circular economy, construction waste, excavation waste, recycled aggregates, life cycle assessment, life cycle costing, and sediment control infrastructure. All search terms were combined using Boolean operators AND and OR to improve both the

Copyright at authors some right reserved this work is licensed under a Creative Commons Attribution-Share Alike 4.0 International License

sensitivity and specificity of the search strategy.

Inclusion and Exclusion Criteria

The inclusion and exclusion criteria were established prior to the search process to ensure objectivity and consistency throughout article selection. Studies considered eligible for inclusion had to be peer-reviewed journal articles published in English and available in full-text format. Furthermore, the studies were required to focus on circular economy, construction waste management, excavation waste management, recycled aggregates, life cycle assessment, or life cycle costing within construction and infrastructure sectors.

Conversely, conference proceedings, editorials, technical notes, commentaries, book reviews, and articles without full-text availability were excluded from the review process. Studies that were not directly related to the construction sector or that did not substantively address circular economy concepts were also excluded. The inclusion and exclusion criteria applied in this study are presented in Tables 3.2 and 3.3.

Table 3.2 Inclusion Criteria

Aspect	Criteria
Publication Period	January 2015 – December 2025
Language	English
Document Type	Peer-reviewed journal articles
Indexing	Scopus
Accessibility	Full-text available
Topic	CE, CDW, Excavation Waste, LCA, LCC

Table 3.3 Exclusion Criteria

Aspect	Criteria
Document Type	Conference papers, editorials, notes, commentaries
Language	Languages other than English
Accessibility	Full-text unavailable
Topic	Not related to construction or circular economy

Copyright at authors some right reserved this work is licensed under a Creative Commons Attribution-Share Alike 4.0 International License

Quality	Does not meet academic standards

PRISMA 2020 Procedure

The article selection process followed the four principal stages of the PRISMA 2020 flow diagram, namely Identification, Screening, Eligibility, and Inclusion. These stages were conducted sequentially to ensure that every article incorporated into the final synthesis was directly relevant to the research objectives.

During the identification stage, all records retrieved from the selected databases were exported into reference management software to facilitate data management and duplicate detection. The initial search yielded 1,487 records. The distribution of records by database source is presented in Table 3.4.

Table 3.4 Results of the Identification Stage

Database	Number of Records
Scopus	742
ScienceDirect	356
Web of Science	221
SpringerLink	98
MDPI	70
Total	1,487

During the screening stage, duplicate records were removed using Zotero software and manual verification. A total of 286 articles were identified as duplicates and removed from the dataset. Subsequently, title and abstract screening was conducted on the remaining 1,201 records. The screening process revealed that 835 articles lacked sufficient relevance to the research objectives and were therefore excluded.

Table 3.5 Results of the Screening Stage

Stage	Number of Articles
Initial Records	1,487
Duplicate Records Removed	286
Records After Deduplication	1,201

Copyright at authors some right reserved this work is licensed under a Creative Commons Attribution-Share Alike 4.0 International License

Articles Excluded Based on Title and Abstract	835
Articles Proceeding to Eligibility Assessment	366

The next stage involved eligibility assessment through comprehensive full-text evaluation. All studies that passed the screening stage were successfully retrieved in full-text format and assessed for topical relevance, methodological quality, scientific contribution, and applicability to the development of a circular economy model for construction excavation waste management.

A total of 274 articles were excluded during this stage because they did not satisfy the eligibility requirements. The primary reasons for exclusion included insufficient discussion of circular economy principles, lack of relevance to construction or excavation waste management, absence of LCA or LCC applications, and inadequate methodological quality.

Table 3.6 Results of the Eligibility Stage

Reason for Exclusion	Number
Insufficient Discussion of Circular Economy	79
Not Related to Construction or Excavation Waste	63
No Discussion of LCA or LCC	51
Focus on Non-Construction Sectors	42
Low Methodological Quality	24
Incomplete Full-Text Availability	15
Total	274

The final stage was inclusion. Upon completion of the entire selection process, 92 articles met all predefined criteria and were incorporated into the systematic review. This number was considered sufficiently representative to provide a comprehensive scientific mapping of circular economy development within the construction sector and excavation waste management research.

Table 3.7 Results of the Inclusion Stage

Stage	Number
Full-Text Articles Assessed	366
Articles Excluded	274
Articles Included in the SLR	92

Copyright at authors some right reserved this work is licensed under a Creative Commons Attribution-Share Alike 4.0 International License

Quality Assessment

To enhance the reliability of the synthesis, all articles that passed the selection process were evaluated using a quality assessment instrument. The assessment considered the clarity of research objectives, methodological appropriateness, data validity, contribution to circular economy knowledge development, and relevance to construction waste management. Articles receiving low quality scores were excluded from the final synthesis.

Table 3.8 Quality Assessment Criteria

Score Range	Category
8–10	High
5–7	Moderate
0–4	Low

Data Synthesis

Data extracted from the selected studies were synthesized using both thematic synthesis and narrative synthesis approaches. The synthesis process focused on identifying research trends, circular economy implementation strategies, construction waste recycling technologies, applications of life cycle assessment and life cycle costing, implementation barriers and enablers, and opportunities for developing circular economy models within SABODAM infrastructure systems. The findings were subsequently used to formulate a CE-LCA-LCC conceptual framework tailored to the characteristics of construction excavation waste management in Indonesia.

Copyright at authors some right reserved this work is licensed under a Creative Commons Attribution-Share Alike 4.0 International License

International Journal of Education, Vocational and Social Science
https://e-journal.citakonsulfindo.or.id/index.php/IJEVSS
E-ISSN : 2963 4954
IJEVSS

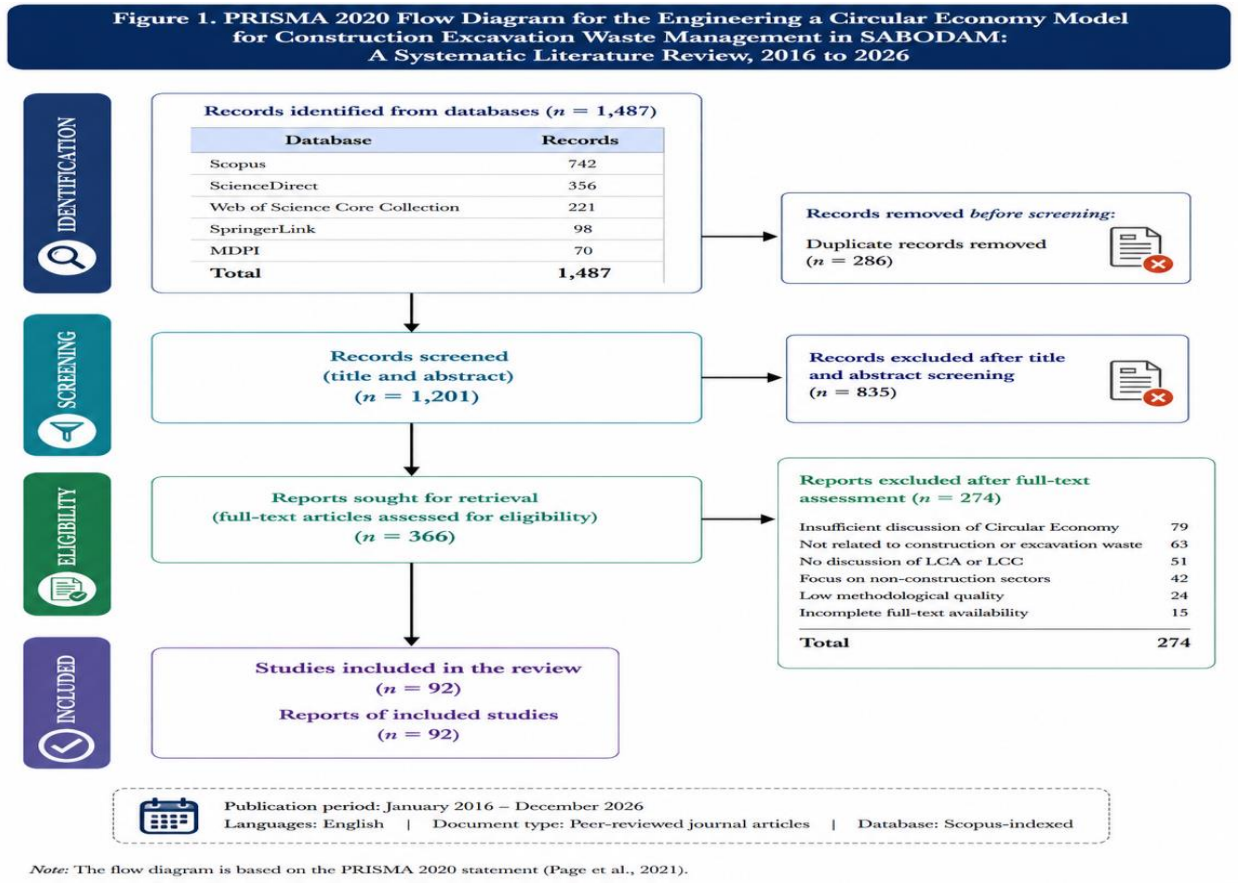


Figure 3.1. PRISMA 2020 Flow Diagram for the Systematic Literature Review of Engineering a Circular Economy Model for Construction Excavation Waste Management in SABODAM (2015–2025).

RESULTS AND DISCUSSION

Overview of the Selected Studies

The PRISMA 2020 selection process resulted in 92 articles that met the inclusion criteria and were included in the final review. The selected studies were published between 2015 and 2025 and primarily focused on circular economy implementation, construction and demolition waste management, excavation waste utilization, recycled aggregates, Life Cycle Assessment (LCA), Life Cycle Costing (LCC), and green innovation in the construction sector. The increasing number of publications during the review period indicates growing academic and industrial interest in sustainable resource management and circular construction practices (Purchase et al.,

Copyright at authors some right reserved this work is licensed under a Creative Commons Attribution-Share Alike 4.0 International License

2022; Ossio et al., 2023; Soto-Paz et al., 2023).

Analysis of publication trends revealed a significant increase in research output after 2020, reflecting global attention toward carbon reduction, resource efficiency, and sustainable infrastructure development. This trend is closely associated with international sustainability initiatives, including the European Green Deal, the United Nations Sustainable Development Goals (SDGs), and national circular economy strategies implemented in many countries (Geissdoerfer et al., 2017; Swarnakar et al., 2024; Hasibuan et al., 2025).

The reviewed studies were predominantly conducted in Europe, China, Australia, and North America, while relatively few studies originated from developing countries. This finding suggests a geographical imbalance in the literature and highlights the need for further research in developing economies where infrastructure expansion and construction waste generation continue to increase rapidly (Purchase et al., 2022; Papamichael & Chrysanthopoulos, 2023; Liu et al., 2021).

Circular Economy Strategies for Construction Excavation Waste Management

The review identified reuse, recycling, and resource recovery as the most frequently adopted circular economy strategies for managing construction excavation waste. Most studies emphasized transforming excavated soil, rock fragments, and sediment materials into secondary construction resources such as aggregates, embankment materials, riprap, and structural fill. These practices significantly reduce landfill disposal while simultaneously decreasing dependence on virgin construction materials (Purchase et al., 2022; Soto-Paz et al., 2023; Gherman et al., 2023).

Several studies demonstrated that circular resource management can reduce raw material extraction by more than 30% while improving material productivity throughout the construction lifecycle. The effectiveness of these strategies depends largely on local material characteristics, transportation distances, technological capabilities, and regulatory support mechanisms (Cristóbal García et al., 2024; Swarnakar et al., 2024; Ossio et al., 2023).

The findings indicate that excavation waste possesses considerable circular potential, particularly in large-scale infrastructure projects where significant quantities of earth materials are generated and consumed simultaneously. This characteristic makes SABODAM construction projects particularly suitable for circular economy implementation because excavation waste can potentially be processed and reused within the same project system, thereby minimizing transportation requirements and associated environmental impacts (Purchase et al., 2022;

Copyright at authors some right reserved this work is licensed under a Creative Commons Attribution-Share Alike 4.0 International License

Hasibuan et al., 2025; Bhavsar & Sridharan, 2025).

Green Innovation as an Enabler of Circular Economy Implementation

A recurring theme across the reviewed literature was the critical role of green innovation in facilitating circular economy implementation. Green innovation encompasses technological, organizational, and managerial innovations designed to improve environmental performance while maintaining economic competitiveness. The reviewed studies consistently identified green innovation as a key driver of resource efficiency, waste minimization, and material circularity within the construction industry (Chen et al., 2022; Singh et al., 2024; Dangelico et al., 2017).

Technological innovations identified in the literature include mobile crushing systems, advanced aggregate processing technologies, digital waste management platforms, artificial intelligence-based optimization systems, Building Information Modeling (BIM), and material tracking technologies. These innovations improve material recovery rates, facilitate waste monitoring, and enhance decision-making processes throughout infrastructure projects (Akanbi et al., 2018; Swarnakar et al., 2024; Hasibuan et al., 2025).

The review further revealed that organizations adopting green innovation strategies were more likely to achieve successful circular economy outcomes. This relationship suggests that technological capability and innovation capacity are essential determinants of circular economy performance. Therefore, green innovation should be considered an integral component of any future circular economy framework developed for SABODAM excavation waste management (Chen et al., 2022; Liu et al., 2021; Singh et al., 2024).

Environmental Performance of Circular Excavation Waste Management

Life Cycle Assessment emerged as the most frequently used methodology for evaluating environmental performance in the reviewed studies. The majority of LCA studies reported that circular economy practices generated substantial environmental benefits compared with conventional waste disposal approaches. These benefits included reductions in greenhouse gas emissions, energy consumption, natural resource extraction, and landfill utilization (Finnveden et al., 2009; Purchase et al., 2022; Soto-Paz et al., 2023).

Several studies reported reductions in carbon emissions ranging from 20% to 60% when recycled aggregates replaced virgin materials. Similar improvements were observed in resource depletion indicators due to reduced extraction of natural aggregates from quarries and river systems. These environmental benefits were particularly significant in projects involving large

Copyright at authors some right reserved this work is licensed under a Creative Commons Attribution-Share Alike 4.0 International License

volumes of excavation materials (Cristóbal García et al., 2024; Swarnakar et al., 2024; Marrucci et al., 2025).

However, environmental performance was found to depend strongly on transportation distances and processing technologies. Excessive transportation requirements can offset environmental benefits associated with recycling activities. Consequently, localized material recovery and reuse strategies were consistently identified as the most environmentally favorable solutions, particularly for infrastructure projects located in remote or mountainous regions such as SABODAM construction sites (Purchase et al., 2022; Ossio et al., 2023; Bhavsar & Sridharan, 2025).

Economic Performance of Circular Excavation Waste Management

Life Cycle Costing analyses consistently demonstrated that circular economy strategies can provide long-term economic advantages despite requiring higher initial investments. The reviewed studies indicated that cost savings were primarily generated through reduced material procurement, lower transportation expenses, decreased landfill fees, and improved resource utilization (Giorgi et al., 2020; Cristóbal García et al., 2024; Purchase et al., 2022).

Several studies reported positive Net Present Value (NPV), favorable Benefit-Cost Ratios (BCR), and acceptable payback periods for recycling and resource recovery initiatives. Economic benefits were particularly pronounced when projects involved large quantities of reusable excavation materials and when recycled products could substitute imported or high-cost virgin aggregates (Swarnakar et al., 2024; Marrucci et al., 2025; Soto-Paz et al., 2023).

The findings suggest that circular economy implementation within SABODAM projects could generate significant economic value because the infrastructure simultaneously produces excavation waste and requires substantial quantities of construction materials. Such conditions create opportunities for closed-loop material systems that reduce overall project costs while enhancing resource efficiency (Purchase et al., 2022; Hasibuan et al., 2025; Cristóbal García et al., 2024).

Barriers and Challenges to Implementation

Despite the demonstrated environmental and economic benefits, several barriers continue to hinder circular economy implementation in construction excavation waste management. The most commonly reported barriers include inadequate regulatory frameworks, insufficient technical standards, low market acceptance of recycled materials, lack of stakeholder

Copyright at authors some right reserved this work is licensed under a Creative Commons Attribution-Share Alike 4.0 International License

awareness, and limited technological capacity (Liu et al., 2021; Purchase et al., 2022; Papamichael & Chrysanthopoulos, 2023).

Technical challenges were also frequently identified, particularly regarding material quality variability, contamination risks, and compliance with engineering specifications. These issues can reduce confidence among contractors, engineers, and project owners regarding the use of recycled materials in infrastructure applications (Alexandridou et al., 2018; Soto-Paz et al., 2023; Swarnakar et al., 2024).

The literature further revealed that institutional and organizational barriers often represent greater obstacles than technological limitations. Successful implementation requires strong collaboration among government agencies, contractors, consultants, academic institutions, and local communities. Consequently, policy support and stakeholder engagement are critical prerequisites for large-scale circular economy adoption within SABODAM infrastructure projects (Liu et al., 2021; Ossio et al., 2023; Hasibuan et al., 2025).

Proposed CE–Green Innovation–LCA–LCC Framework for SABODAM

Based on the synthesis of the reviewed literature, a conceptual framework integrating Circular Economy, Green Innovation, Life Cycle Assessment, and Life Cycle Costing is proposed for SABODAM construction excavation waste management. The framework positions circular economy principles as the foundation for resource recovery and material circularity, while green innovation functions as the enabling mechanism supporting technological advancement and operational efficiency (Chen et al., 2022; Singh et al., 2024; Swarnakar et al., 2024).

Within this framework, excavation waste generated during SABODAM construction is transformed into reusable construction materials through innovative processing technologies. Environmental performance is evaluated through LCA, while economic feasibility is assessed using LCC. The integration of these dimensions supports evidence-based decision-making and enables the optimization of environmental, economic, and resource-efficiency outcomes simultaneously (Purchase et al., 2022; Marrucci et al., 2025; Cristóbal García et al., 2024).

The proposed framework addresses a significant gap in the existing literature by providing a comprehensive approach specifically tailored to excavation waste management in hydraulic and disaster mitigation infrastructure. The framework also establishes a foundation for future empirical research and practical implementation within SABODAM projects in Indonesia and other developing countries. This contribution represents the principal theoretical and practical outcome of the present systematic literature review (Ossio et al., 2023; Hasibuan et al., 2025; Bhavsar &

Copyright at authors some right reserved this work is licensed under a Creative Commons Attribution-Share Alike 4.0 International License

Sridharan, 2025).

DISCUSSION

The findings of this systematic literature review demonstrate that the integration of Circular Economy (CE), Green Innovation, Life Cycle Assessment (LCA), and Life Cycle Costing (LCC) provides a comprehensive approach for improving the sustainability of construction excavation waste management. The reviewed studies consistently indicate that excavation waste should be recognized as a valuable secondary resource rather than a disposal burden, as it can be reused and recycled for various construction applications, thereby reducing dependence on virgin materials and minimizing environmental impacts. Furthermore, the literature highlights that Green Innovation plays a critical role in facilitating circular economy implementation through the adoption of advanced technologies, digital tools, and innovative management practices that enhance resource recovery, material traceability, and operational efficiency. These findings support the growing consensus that sustainable infrastructure development requires an integrated framework that simultaneously addresses environmental performance, economic viability, and resource circularity (Geissdoerfer et al., 2017; Chen et al., 2022; Purchase et al., 2022).

The review also reveals a significant research gap regarding the application of circular economy principles in hydraulic and disaster mitigation infrastructure, particularly within SABODAM construction projects. While extensive studies have examined circular construction practices in buildings, transportation infrastructure, and urban development, limited attention has been given to the management of excavation waste generated by sediment-control and disaster-resilient infrastructure systems. The evidence suggests that SABODAM projects offer substantial opportunities for establishing closed-loop material systems because excavation materials generated during construction can potentially be processed and reused within the same project lifecycle. Consequently, the proposed CE–Green Innovation–LCA–LCC framework provides a promising foundation for enhancing environmental sustainability, resource efficiency, and economic performance in SABODAM development. The framework also contributes to the advancement of sustainable infrastructure practices by promoting the integration of innovative technologies, circular resource management strategies, and life-cycle-based decision-making processes within disaster mitigation projects (Ossio et al., 2023; Swarnakar et al., 2024; Hasibuan et al., 2025).

Copyright at authors some right reserved this work is licensed under a Creative Commons Attribution-Share Alike 4.0 International License

CONCLUSION

This systematic literature review demonstrates that the integration of Circular Economy (CE), Green Innovation, Life Cycle Assessment (LCA), and Life Cycle Costing (LCC) offers a comprehensive and sustainable approach to construction excavation waste management. The findings indicate that excavation waste generated from construction activities possesses significant potential to be transformed into valuable secondary resources through reuse, recycling, and resource recovery strategies. The reviewed literature consistently highlights that circular economy implementation can reduce dependence on virgin materials, minimize waste disposal, lower greenhouse gas emissions, and improve overall resource efficiency. Furthermore, Green Innovation has been identified as a critical enabler that supports the adoption of advanced technologies, innovative management practices, and digital solutions necessary for enhancing material circularity and sustainability performance within construction projects (Geissdoerfer et al., 2017; Chen et al., 2022; Purchase et al., 2022).

The review also reveals a substantial research gap concerning the application of circular economy principles to excavation waste management in hydraulic and disaster mitigation infrastructure, particularly within SABODAM projects. Existing studies predominantly focus on buildings, urban construction, and transportation infrastructure, while limited attention has been given to sediment-control and disaster-resilient infrastructure systems. Based on the synthesis of the selected studies, this review proposes an integrated CE–Green Innovation–LCA–LCC framework as a foundation for sustainable SABODAM construction excavation waste management. The proposed framework is expected to support environmentally responsible decision-making, improve economic efficiency, and strengthen resource circularity in infrastructure development. Future research should focus on empirical validation of the framework through case studies and quantitative assessments to further evaluate its practical applicability and effectiveness in real-world SABODAM projects (Ossio et al., 2023; Swarnakar et al., 2024; Hasibuan et al., 2025).

REFERENCES

Gálvez-Martos, J. L., Styles, D., Schoenberger, H., & Zeschmar-Lahl, B. (2018). Construction and demolition waste best management practice in Europe. *Resources, Conservation and Recycling, 136*, 166–178. https://doi.org/10.1016/j.resconrec.2018.04.016

Honic, M., Kovacic, I., Rechberger, H., & Fellner, J. (2019). Sustainability assessment of demolition

Copyright at authors some right reserved this work is licensed under a Creative Commons Attribution-Share Alike 4.0 International License

waste management. *Waste Management, 102*, 609–621. https://doi.org/10.1016/j.wasman.2019.10.034

Iacovidou, E., Hahladakis, J. N., & Purnell, P. (2021). A systems thinking approach to understanding construction waste management. *Journal of Cleaner Production, 279*, 123683. https://doi.org/10.1016/j.jclepro.2020.123683

Islam, N., Sadiq, R., & Hewage, K. (2024). Review on sustainable construction and demolition waste management. *Sustainability, 16*(8), 3289.

Krajewska, A., & Kowalski, Z. (2025). Circular economy in the construction sector in materials, processes and case studies. *Sustainability, 17*(15), 7029.

Leising, E., Quist, J., & Bocken, N. (2018). Circular economy in the building sector. *Journal of Cleaner Production, 181*, 976–991. https://doi.org/10.1016/j.jclepro.2017.12.258

Lieder, M., & Rashid, A. (2016). Towards circular economy implementation: A comprehensive review. *Journal of Cleaner Production, 115*, 36–51. https://doi.org/10.1016/j.jclepro.2015.12.042

López Ruiz, L. A., Roca Ramón, X., & Gassó Domingo, S. (2020). Circular economy in the construction and demolition waste sector. *Journal of Cleaner Production, 248*, 119238. https://doi.org/10.1016/j.jclepro.2019.119238

Moraga, G., Huysveld, S., Mathieux, F., Blengini, G., Alaerts, L., Van Acker, K., de Meester, S., & Dewulf, J. (2019). Circular economy indicators. *Journal of Industrial Ecology, 23*(3), 517–533. https://doi.org/10.1111/jiec.12754

Nußholz, J. L. K. (2018). Circular business models and resource efficiency. *Resources, Conservation and Recycling, 129*, 308–317. https://doi.org/10.1016/j.resconrec.2017.10.027

Oluleye, B. I., Chan, D. W. M., Saka, A. B., & Olawumi, T. O. (2022). Circular economy research in construction waste management. *Sustainable Production and Consumption, 30*, 1–16.

Osmani, M. (2020). Construction waste minimisation in the UK. *Proceedings of the Institution of Civil Engineers: Waste and Resource Management, 173*(3), 103–114.

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

Shooshtarian, S., Maqsood, T., Caldera, S., & Ryley, T. (2022). Transformation towards a circular economy in the Australian construction and demolition waste management system. *Sustainable Production and Consumption, 30*, 89–106. https://doi.org/10.1016/j.spc.2021.11.032

Starčev-Curčin, A., & colleagues. (2024). Circular economy and its barriers to implementation in

Copyright at authors some right reserved this work is licensed under a Creative Commons Attribution-Share Alike 4.0 International License

construction. *Building Materials and Structures*.

Yuan, H. (2017). A SWOT analysis of successful construction waste management. *Journal of Cleaner Production, 39*, 1–8.

Yuan, H., Chini, A. R., Lu, Y., & Shen, L. (2018). A dynamic model for assessing construction waste management. *Waste Management, 79*, 37–47.

Zhao, W., Leeftink, R. B., & Rotter, V. S. (2016). Evaluation of construction and demolition waste recycling. *Waste Management, 56*, 209–220. https://doi.org/10.1016/j.wasman.2016.07.019

Copyright at authors some right reserved this work is licensed under a Creative Commons Attribution-Share Alike 4.0 International License