Eco-Balanced Construction Methods in the Management of Sustainable Development Within a Circular Economy

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Abstract

The management of sustainable development in Armenia's economy is closely associated with the need to design and implement new sustainable methods and models of production and consumption aimed at fostering economic growth, advancing social development, and mitigating environmental risks at their source. Eco-balanced construction methods play a pivotal role among modern approaches to construction production. The sustainable development of a national economy is largely determined by environmental safety parameters, which are grounded in the condition of the environment and the potential of natural resources.A primary source of environmental degradation is the increasing volume of industrial waste, including construction and demolition waste. The reduction of construction waste through recycling and secondary use constitutes an effective instrument for ensuring sustainable economic development. This article examines the role and significance of an eco-balanced circular economy in managing sustainable development, using the construction industry as a case study. It further analyzes the regulatory and legal framework governing waste management in the Republic of Armenia, as well as conceptual approaches to the circular economy presented in both domestic and international scholarly literature. Particular attention is given to methods of processing secondary resources in construction, including recycling, downcycling, and upcycling.

The theoretical foundation of the study is reinforced through the integration of contemporary international research emphasizing the importance of circular economy principles in the construction sector. Recent studies indicate that construction is a key sector for climate change mitigation and resource efficiency, given its high energy consumption and substantial share of emissions (Finamore, & Oltean-Dumbrava, 2024). At the same time, the academic literature highlights that the practical implementation of circular economy principles remains fragmented and often fails to encompass the full life cycle of construction projects, from design to deconstruction (Marchi, et al., 2024).

Moreover, studies on environmental impact assessment reveal the absence of unified and systematic evaluation tools capable of integrating environmental, economic, and technological indicators into a comprehensive framework (Muñoz, et al., 2023). In this context, the present research addresses this gap by proposing an integrated approach that combines recycling methods, material flow management, and budget efficiency assessment, thereby enhancing the applicability of circular economy principles in the construction sector.

The study also analyzes the "circular" use of construction materials (specifically asphalt concrete) within the framework of national projects in the Republic of Armenia. A methodology has been developed and tested to assess the impact of eco-balanced construction methods on project implementation and budget reduction. Based on the findings, recommendations are provided for optimizing and improving the efficiency of budgetary expenditures through the introduction of recycling systems in construction, particularly in the rehabilitation of highway networks.

Keywords: sustainable development, circular economy, recycling, construction waste, eco-balanced methods

1. Introduction

Environmental challenges associated with excessive resource consumption and escalating pollution levels are closely linked to the construction sector, which accounts for up to 36% of global energy consumption and approximately 40% of total waste generation (United Nations Environment Programme (UNEP) and Global

Alliance for Buildings and Construction (GlobalABC), 2026). The prevailing linear economic model in construction has proven to be unsustainable, thereby necessitating a fundamental paradigm shift toward the Circular Economy (CE).

The Circular Economy represents an economic system designed to eliminate waste and ensure the continuous utilization of resources, grounded in the principles of repair, reuse, and regeneration (Ellen MacArthur Foundation, 2019). Within this framework, eco-balanced construction emerges as a practical and scalable mechanism for implementing circular economy principles across all stages of the construction lifecycle—from design and construction to operation and demolition.

Contemporary global challenges, including resource depletion, rising energy demand, and environmental degradation, are particularly pronounced in the construction sector. Traditionally, this sector has been one of the largest consumers of raw materials and generators of waste. The linear "take–make–dispose" model has reached its functional limits, revealing significant risks of irreversible resource depletion and ecological imbalance.

Under these conditions, the Circular Economy has become a central paradigm of sustainable development, aiming to maximize resource efficiency while minimizing waste generation through the transformation of waste into valuable inputs for new production cycles.

This study investigates how eco-balanced construction practices can support the practical implementation of circular-economy principles in sustainable development management.

2. Materials and Methods

The concept of sustainable economic development constitutes a central paradigm in 21st-century governance, wherein environmental security and the identification of innovative approaches to environmental protection play a decisive role [11]. Sustainable development reflects a state of dynamic equilibrium among economic, social, and environmental subsystems, characterized by both qualitative and quantitative improvements in national development, regional competitiveness, and societal well-being.

The construction sector represents a critical component of sustainable national development, not only due to its economic and technological significance but also because of its substantial environmental impact. The transition toward an eco-balanced circular economy—one that accounts for the long-term interdependencies between economic and ecological systems—is essential for ensuring regional and national sustainability.

An eco-balanced economy may be defined as a development model based on the rational utilization of resources, in which human activity is considered an integral element of the eco-economic system (Amirova, Sargina, & Kondrateva, 2022; Kuzmenchuk, & Tishchenko, 2019, May 24). From the standpoint of environmental protection and resource management, the primary challenges include increasing anthropogenic pressures and the rapid growth of industrial waste, particularly construction and demolition waste (CDW), which outpaces current recycling and disposal capacities. Consequently, the reuse and recycling of materials are critical for advancing green construction practices and achieving sustainable development objectives.

reflecting the specific characteristics of construction products, technologies, working conditions, and production organization.

The effective management of construction waste is therefore of paramount importance. Recycling construction materials not only contributes to environmental preservation but also reduces the demand for primary resources, lowers material acquisition and transportation costs, minimizes landfill use, and enhances the efficiency of budget allocation at the project planning stage.

The development and implementation of construction waste recycling programs—particularly at the regional level—can significantly reduce public expenditures by lowering logistics, handling, and storage costs. In addition, such programs can stimulate job creation, enhance the operational efficiency of recycling enterprises, promote the production of innovative materials, and improve environmental conditions within local communities.

The effectiveness of construction resource recycling strategies is a key determinant of sustainable development at national, regional, and enterprise levels. It contributes to resource conservation, environmental balance, increased production efficiency, and positive socio-economic outcomes. However, despite its importance, the integration of eco-sustainable construction methods and construction waste recycling practices remains insufficiently developed, highlighting a critical research gap addressed by this study.

A review of both domestic and international literature reveals a strong correlation between the advancement of circular economy principles and the achievement of sustainable development goals in the construction sector. Existing studies consistently emphasize that the circular economy generates positive economic, environmental, and social impacts through the reintegration of resources into production cycles.

The transition to a circular economy requires comprehensive systemic changes, including technological innovation, reform of environmental policies, institutional support, and a shift toward responsible production and consumption patterns. Notably, certain strands of the literature lack a clear differentiation between various recycling methods and do not provide sufficiently precise definitions or classifications of concepts such as recycling, downcycling, and resource revitalization within sustainable development frameworks.

In contrast, international research adopts a lifecycle-oriented perspective, encompassing stages such as design, maintenance, repair, reuse, refurbishment, reconstruction, and recycling. These studies also introduce advanced methodologies for evaluating resource circulation and propose new performance indicators, thereby expanding both the theoretical and practical dimensions of the circular economy.

Within the framework of national sustainable development strategies, the transition toward an eco-balanced economy should be implemented through integrated public policies that align economic, environmental, and social objectives. Regional sustainability, in particular, depends on structural transformations aimed at increasing environmentally friendly production processes, promoting efficient resource utilization, stimulating employment, and enhancing environmental performance. A critical component of this transition is the reduction of construction and demolition waste.

Construction and demolition waste (CDW) is defined as waste generated from construction, maintenance, renovation, demolition, and reconstruction activities, as well as from damage caused by natural disasters (Note 1). Due to its heterogeneous composition, CDW presents significant challenges in terms of management and logistics. However, its recycling and reuse as secondary raw materials, energy sources, or construction inputs offer substantial opportunities for reducing waste volumes and improving resource efficiency.

3. Results and Discussion

The application of circular economy principles in the construction sector entails a fundamental transition from a linear lifecycle model to a closed-loop system. The core principles of this transformation include:

- **Design for Disassembly and Reuse**

Buildings and structures are designed to enable easy dismantling, repair, reuse, and recycling of components at the end of their lifecycle.

- **Closed Material Loops**

Priority is given to the use of secondary raw materials and recycled resources, supported by material tracking systems that ensure transparency and traceability throughout the project lifecycle.

- **Waste Reduction and Resource Recovery**

Construction and demolition waste are reclassified as valuable secondary resources capable of re-entering production cycles.

- **Energy Efficiency and Renewable Energy Integration**

Energy consumption is minimized during the operational phase through the use of renewable energy sources, including solar and wind technologies.

- **Biocompatibility and Reduced Environmental Impact**

The use of non-toxic, environmentally friendly materials is prioritized, alongside the minimization of ecological footprints throughout all construction phases.

3.1 Core Methods of Eco-Balanced Construction

Eco-balanced construction encompasses a comprehensive set of methods and technologies that facilitate the practical implementation of circular economy principles within the construction sector. These approaches focus on enhancing resource efficiency, optimizing energy use, promoting material recirculation, and reducing environmental impacts. Importantly, they ensure that all stages of the construction lifecycle—from initial design to final demolition—contribute coherently to the achievement of sustainable development objectives.

The discussion of the **main methods of solid waste recycling**, using the **example of waste generated by the construction industry**, has demonstrated that these methods **vary in terms of efficiency** (Figure 1).

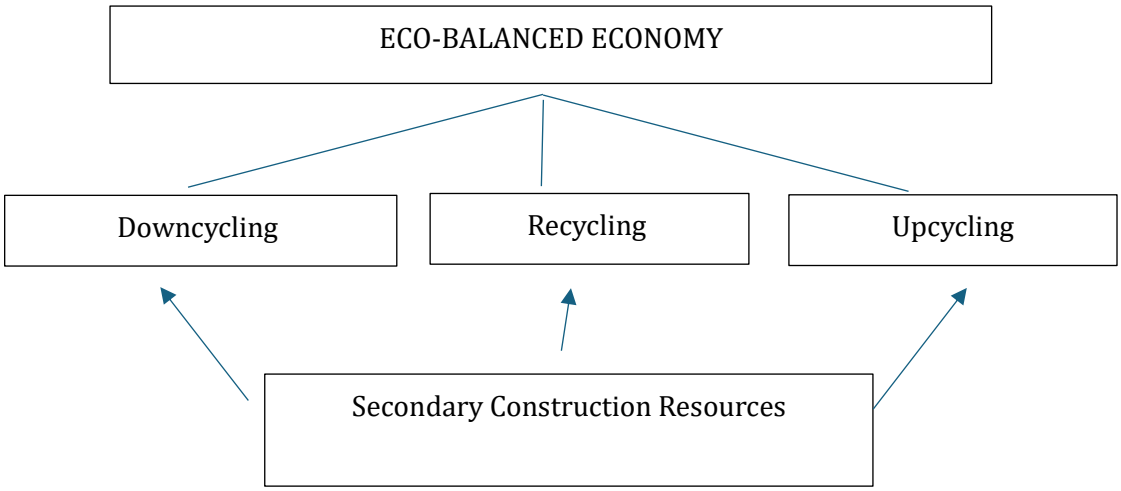


Figure 1. Methods of secondary resource recycling

The recycling method involves the processing of materials through a coordinated system of organizational, economic, technical, and technological measures, enabling their reintegration into production and economic cycles. Unlike other forms of material recovery, this approach preserves the intrinsic properties and quality of the material, allowing it to re-enter the same lifecycle without degradation (Figure 2).

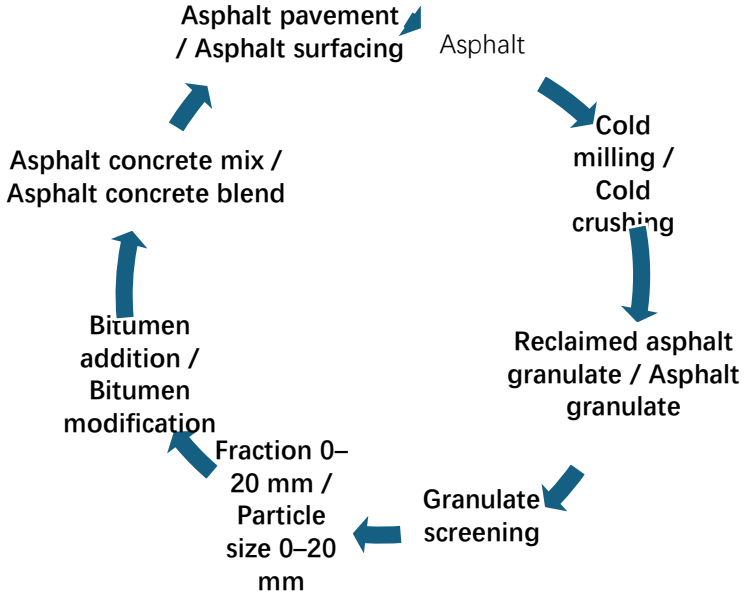


Figure 2. Example of recycling method through asphalt reprocessing

Downcycling refers to a material processing approach whereby a set of organizational, economic, and technical measures is applied to transform waste into materials of reduced quality or functionality. This phenomenon typically arises because the intrinsic properties of the material—particularly its structural integrity—deteriorate during repeated processing cycles. As a result, the recovered material cannot be reintroduced into its original production cycle and is instead redirected to lower-value applications (Figure 3).

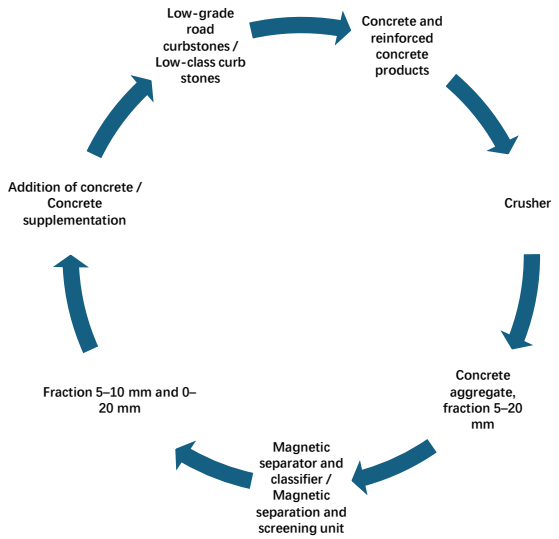


Figure 3. Example of downcycling method through concrete and reinforced concrete product recycling

The upcycling method entails the transformation of materials through an integrated system of organizational, economic, technical, and technological measures, resulting in products or materials of higher value than their original form (Figure 4). From the standpoint of energy efficiency and labor intensity, this approach is widely regarded as one of the most environmentally sustainable strategies. In this context, the "history" of waste is effectively embedded within the lifecycle of a new product, thereby extending material value and functionality. However, it should be noted that products derived from upcycled materials are typically more labor-intensive to produce, which may lead to higher final costs compared to conventional alternatives.

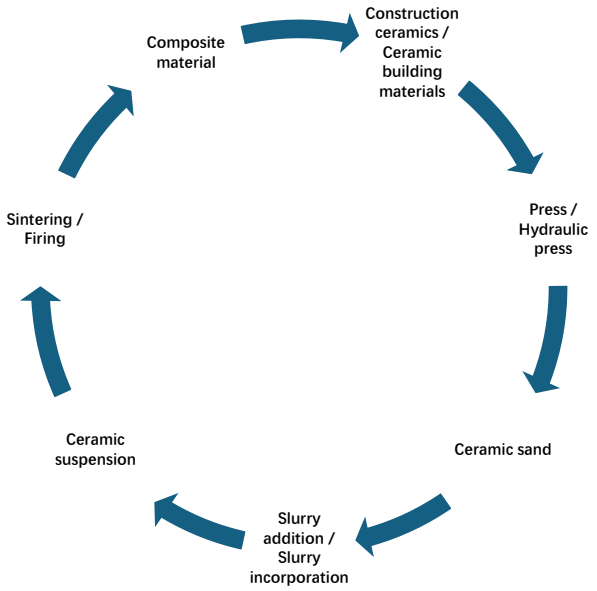


Figure 4. Example of Upcycling Method through Concrete and Reinforced Concrete Product Recycling

The utilization of construction waste processed through the aforementioned methods as secondary building materials generates significant environmental benefits while simultaneously contributing to the reduction of public expenditures associated with the development of social infrastructure. The transition toward the "circular" use of construction materials necessitates the establishment of a comprehensive economic incentive framework that renders recycling, downcycling, upcycling, and the use of secondary materials more economically viable than landfill disposal or incineration. The design and implementation of such a framework require robust

economic justification of environmentally sustainable practices, supported by an appropriate legislative and institutional environment.

The principal methods of municipal solid waste (MSW) management—mechanical-biological treatment, thermal processing, and material recovery—may be examined as distinct technological approaches, each characterized by specific advantages and limitations. A comparative assessment of these methods should be conducted based on environmental impact, economic feasibility, and resource efficiency.

3.2 Mechanical-Biological Treatment (MBT)

MBT represents an integrated waste management approach combining mechanical sorting with biological processing. This method comprises two main stages:

- **Mechanical separation**, involving the use of sieves, magnetic separators, and air classifiers to fractionate waste into plastics, paper, metals, glass, and organic components.
- **Biological treatment**, whereby the organic fraction undergoes either composting or anaerobic digestion.

Composting is an aerobic process in which microorganisms decompose organic matter, producing compost suitable for use as an organic fertilizer. Anaerobic digestion occurs in oxygen-free conditions, generating biogas (primarily methane and carbon dioxide), which can be utilized for heat and electricity production.

The advantages of MBT include a reduction in the volume of waste directed to landfills, the generation of value-added by-products (such as compost and biogas), and relatively moderate operational costs. However, its limitations include the requirement for effective pre-sorting, potential odor emissions, and variability in compost quality depending on input material purity.

3.3 Thermal Treatment Methods

Thermal treatment methods involve high-temperature processing of waste to reduce its volume and recover energy. The principal technologies include:

- **Incineration**, which entails the combustion of waste at temperatures ranging from 850°C to 1200°C in specialized facilities. This process enables:
- **Energy recovery**, through the conversion of heat into electricity via steam turbines;
- **Generation of slag and ash**, which may be reused in construction applications, such as road building.

The key advantages of incineration include substantial waste volume reduction (up to 90%), energy generation, and the destruction of hazardous organic compounds. Its limitations involve high capital investment requirements, the potential formation of toxic by-products (e.g., dioxins and furans) under suboptimal operating conditions, and the necessity for advanced flue gas treatment systems.

- **Pyrolysis and gasification**, which are advanced thermochemical processes conducted under limited oxygen conditions. Pyrolysis occurs at temperatures between 400°C and 800°C, producing pyrolysis oil, gas, and solid carbon residues. Gasification takes place at higher temperatures (800–1500°C), generating synthesis gas (a mixture of CO and H_2), which can be used as a fuel or chemical feedstock.

These technologies offer advantages such as higher energy efficiency relative to conventional incineration, lower emissions, and the potential recovery of valuable chemical products. However, their widespread application is constrained by technological complexity, high investment costs, stringent feedstock requirements, and limited large-scale deployment.

3.4 Material Recovery (Recycling)

Material recovery (recycling) involves the transformation of waste into secondary raw materials for the production of new goods. Within the framework of a circular economy, this process typically includes the following stages:

1. **Collection and sorting** at dedicated facilities;
2. **Cleaning and processing**, including washing, shredding, and melting;
3. **Manufacturing of new products** from recovered materials.

The advantages of recycling include the conservation of natural resources, significant energy savings (for example, aluminum recycling can reduce energy consumption by up to 95% compared to primary production), and a decrease in landfill volumes. Nevertheless, its effectiveness depends on efficient waste segregation at the source, stable markets for secondary materials, and the resolution of technological challenges associated with complex materials such as multilayer composites.

A critical constraint across all waste management approaches remains the lack of effective source separation. Without it, neither circular material flows nor efficient mechanical-biological treatment can be fully realized. Accordingly, the future of sustainable waste management lies in the development of integrated systems in which

different methods are applied in a complementary manner, following a hierarchical structure:

- **Reduction and reuse** as primary priorities;
- **Sorting and recycling** as preferred strategies;
- **Mechanical-biological treatment** for organic waste streams;
- **Thermal processing** for residual waste with energy recovery;
- **Final disposal** of inert and unavoidable residues in environmentally controlled landfills.

Such an integrated approach ensures the maximization of resource efficiency, minimization of environmental impact, and alignment with the core principles of the circular economy in the construction sector.

4. Conclusion

This study substantiates, at both theoretical and applied levels, that the systemic integration of eco-balanced construction methods can serve as an effective instrument for managing sustainable development within the framework of a circular economy. In contrast to existing research, the scientific novelty of this work lies in the development of a combined methodological approach that integrates the principles of material resource circulation, construction waste recycling technologies, and budget efficiency assessment tools into a unified analytical system.

One of the key distinguishing outcomes of the study is the comprehensive evaluation of construction waste processing methods—namely recycling, downcycling, and upcycling—taking into account not only their technological effectiveness but also their economic feasibility and managerial applicability. The proposed methodology enables the quantitative assessment of resource savings, cost optimization potential, and environmental impact reduction at both the project planning and implementation stages.

The practical value of the research is associated with adapting the proposed approach to the specific characteristics of Armenia's construction sector.

A further methodological contribution is the reconceptualization of construction waste as a secondary economic resource, implying a transition from a linear "production–consumption–disposal" model to a closed-loop management system. Such an approach establishes a new paradigm for material flow management aimed at ensuring long-term sustainability and efficient resource allocation.

Overall, the findings can be applied in both public policy development and the planning of investment and infrastructure projects, contributing to increased competitiveness in the construction sector and the achievement of sustainable development goals.

Future research should focus on the implementation of digitalized management systems, the development of eco-balanced materials, and the improvement of economic incentive mechanisms to accelerate the transition toward a circular economy-based construction model.

This study significantly differs from prior research in the field due to its systemic and integrated approach. While earlier studies have largely been limited to theoretical justifications of the circular economy or the examination of individual construction waste recycling technologies, this work develops a comprehensive methodological framework that integrates recycling methods, material flow circulation, and budget efficiency assessment into a single management system. Particular attention is given to the comparative evaluation of recycling, downcycling, and upcycling, incorporating not only technological but also economic and managerial criteria, thereby overcoming the fragmented approaches prevalent in the field.

The scientific and practical advancement of the research is also reflected in the quantitative assessment of the interrelationship between technological and economic components, enabling the justification of resource savings and cost optimization already at the design stage. Furthermore, the proposed approach is tailored to the conditions of the Republic of Armenia, taking into account the specific features of the local construction market, resource constraints, and infrastructure development needs. An important innovation of the study is the reinterpretation of construction waste as a secondary economic resource, facilitating the transition from a linear model to a closed-loop management system and establishing a practical foundation for the implementation of sustainable development strategies.

References

Adams, K. T., *et al.*. (2017). Circular economy in construction: A review of current knowledge and a research agenda. *Waste Management, 60,* 1-12.

Amirova, N. R., Sargina, L. V., & Kondrateva, Y. E. (2022). Main Approaches to the Implementation of the Circular Economy, Post-Soviet Mainland № 1(33). Scientific and Analytical Journal, 89-106.

Ellen MacArthur Foundation. (2019). Completing the Picture: How the Circular Economy Tackles Climate Change.

Finamore, M., & Oltean-Dumbrava, C. (2024). *Circular economy in construction: findings from a literature review.*

Göswein, V., *et al.*. (2021). Land-saving, resource-efficient, and circular construction: A review of environmental assessment tools. *Journal of Cleaner Production*, 286.

Kuzmenchuk, I. V., & Tishchenko, L. I. (2019, May 24). Development of an eco-balanced economy based on harmonious interactions between economic, environmental, and social systems. In *Modern Innovative Technologies and Sustainable Development Issues in the Context of the Digital Economy: Proceedings of the XIII International Scientific and Practical Conference*, Minsk (2019, pp. 143–146). Minsk: Kolorgrad.

Lyaskovskaya, E. A. (2017). Sustainable development management in terms of inclusive growth and the green economy. *Questions of Management*, *4*(47).

Marchi, *et al*.. (2024). *Barriers and drivers to advance circularity in construction*.

Muñoz, *et al.*. (2023). *Environmental assessment of circular economy in construction*

United Nations Environment Programme (UNEP) and Global Alliance for Buildings and Construction (GlobalABC). (2026). *Global Status Report for Buildings and Construction 2025–2026*. Nairobi: UNEP.

Note

Note 1. Law on Waste of the Republic of Armenia, adopted on November 24, 2004.

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