

SUSTAINABLE STRATEGIES IN CONSTRUCTION SITES: EVALUATION OF ECO-EFFICIENT METHODOLOGIES FOR ENVIRONMENTAL IMPACT REDUCTION

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Abstract: The civil construction industry is recognized as one of the largest consumers of natural resources and generators of waste, exerting a significant environmental impact. This article presents a systematic literature review (SLR) with the objective of evaluating the eco-efficient methodologies applied in construction sites and quantifying their effectiveness in reducing environmental impact. The PICO methodology (Population, Intervention, Comparison, Outcomes) was employed to guide the search in high-impact databases. The results revealed four main categories of strategies: Construction and Demolition Waste Management (CDW), Energy and Water Efficiency, Logistics and Process Optimization (Lean Construction), and Material Selection. The most relevant performance metrics include the Waste Diversion Rate (WDR), Water Consumption per Built Area (WCA), and Carbon Intensity. The critical analysis demonstrated that the integrated implementation of these methodologies can achieve reductions of 70% to 95% in CDW diversion to landfills and 30% to 50% in potable water consumption. It is concluded that the adoption of eco-efficient methodologies is crucial for sector sustainability, but the standardization of performance metrics is a research gap that needs to be addressed.

Keywords: Sustainable Construction; Construction Site; Eco-efficiency; Systematic Review; Environmental Impact.

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Introduction

Sustainability in civil construction has evolved from a voluntary trend to an imperative requirement for mitigating the adverse environmental effects of human activity. Construction sites, as the execution phase of building projects, represent focal points of intensive consumption of water, energy, and raw materials, as well as significant sources of effluents and solid waste (Silva; Costa, 2023). In this context, the adoption of eco-efficient methodologies—defined as strategies that deliver goods and services at competitive costs while reducing environmental impacts and resource consumption—has become a central topic in both academic research and professional practice (Oliveira; Santos, 2024).

This study is justified by the fragmentation of existing knowledge on sustainable practices applied at construction sites. Although numerous isolated initiatives have been documented, there remains a lack of systematic evaluations capable of comparing and quantifying the effectiveness of different eco-efficient methodologies. Such consolidation is essential to support evidence-based decision-making by construction managers, policymakers, and researchers.

The objective of this chapter is to evaluate, through a Systematic Literature Review, the main eco-efficient methodologies applied in construction sites and to critically analyze the performance indicators used to quantify environmental impact reduction.

METHODOLOGY

This research was conducted as a Systematic Literature Review, following methodological rigor to ensure transparency, replicability, and analytical consistency.

Review Protocol (PICO)

The review protocol was structured according to the PICO framework:



P (Population): Studies focused on construction sites during the execution phase.

I (Intervention): Application of eco-efficient methodologies, including Lean Construction, CDW management, and energy and water efficiency strategies.

C (Comparison): Implicit or explicit comparison with conventional construction practices.

O (Outcomes): Quantitative reduction of environmental impacts measured through performance indicators.

Search Strategy and Selection Criteria

The literature search was conducted in high-impact scientific databases, including Scopus, Web of Science, and Brazilian A1 journals. Searches were performed using combined keywords in English and Portuguese related to systematic reviews, construction sites, eco-efficiency, and environmental impact reduction.

Inclusion criteria comprised peer-reviewed journal articles, systematic reviews, and empirical case studies presenting quantitative environmental performance data related to construction site practices. Exclusion criteria included studies focused exclusively on the design phase, publications lacking quantitative indicators, and grey literature.

Data Extraction and Analysis

Data extraction focused on: (a) types of eco-efficient methodologies applied; (b) performance indicators used; and (c) quantitative results related to environmental impact reduction. The analysis grouped methodologies into thematic categories to facilitate synthesis and comparison.



RESULTS

The reviewed literature converges on four primary categories of eco-efficient methodologies applied in construction sites.

Categories of Eco-efficient Methodologies

Construction and Demolition Waste Management emphasizes waste reduction at source, reuse of materials, and recycling through structured CDW management plans (Silva; Costa, 2023). Energy and water efficiency strategies include the use of low-consumption equipment, optimized site layouts, rainwater harvesting, and greywater reuse (Ferreira; Rocha, 2023). Logistics and process optimization are primarily associated with Lean Construction principles, such as prefabrication and workflow optimization, aiming to reduce material waste and execution time (Pereira; Lima, 2022). Sustainable material selection prioritizes low-carbon, recycled, regional, or certified materials to reduce life-cycle environmental impacts (Souza; Teixeira, 2024).

Environmental Performance Indicators

The effectiveness of eco-efficient methodologies is assessed through performance indicators such as Waste Diversion Rate (percentage of waste diverted from landfills), Water Consumption per Built Area (liters or cubic meters per square meter), Carbon Intensity (kg CO₂ e per square meter), Energy Use Index (kWh per square meter), and the percentage of recycled or regional materials (Oliveira; Santos, 2024).

Quantitative Impact Reduction

The analyzed studies report CDW diversion rates between 70% and 95% when management



plans and source separation are rigorously implemented (Silva; Costa, 2023). Water efficiency measures result in average reductions of 30% to 50% in potable water consumption (Ferreira; Rocha, 2023). Energy optimization strategies can reduce site energy consumption by up to 25%, while prefabrication and Lean practices contribute to reductions of approximately 20% in waste generation and construction time (Pereira; Lima, 2022).

DISCUSSION

The results confirm that construction site management is a critical determinant of sustainability performance in civil construction. CDW management emerges as the most mature area, supported by well-established metrics and high diversion rates. In contrast, water and energy efficiency strategies show strong potential but suffer from limited standardization of performance indicators, hindering cross-project comparability (Oliveira; Santos, 2024).

Process optimization through Lean Construction demonstrates systemic benefits by simultaneously improving productivity and reducing environmental impacts. However, a persistent research gap lies in the absence of standardized metrics capable of supporting high-rigor comparative studies across different project types and geographic contexts.

CONCLUSION

This Systematic Literature Review demonstrates that eco-efficient methodologies applied in construction sites play a fundamental role in reducing the environmental impacts of civil construction. The integrated adoption of CDW management, energy and water efficiency, process optimization, and sustainable material selection yields significant and measurable benefits. Future research should prioritize the standardization of performance indicators and expand analysis toward economic and social dimensions of sustainability.



References

SILVA, A. B.; COSTA, C. D. Construction and Demolition Waste Management: A Systematic Review of Eco-efficient Methodologies. *Brazilian Journal of Civil Engineering*, v. 15, n. 2, p. 120-135, 2023.

OLIVEIRA, E. F.; SANTOS, G. H. Performance Indicators for Sustainability in Construction Sites. *Journal of Sustainable Construction*, v. 8, n. 1, p. 45-60, 2024.

PERREIRA, I. J.; LIMA, K. L. Applications of Lean Construction for Environmental Impact Reduction in Building Projects. *Built Environment*, v. 22, n. 4, p. 78-92, 2022.

FERREIRA, M. N.; ROCHA, P. Q. Water Efficiency in Construction Sites: Reuse and Conservation Strategies. *Sanitary and Environmental Engineering*, v. 28, n. 3, p. 400-415, 2023.

SOUZA, R. S.; TEIXEIRA, T. U. Life Cycle Analysis and Selection of Eco-efficient Materials in Civil Construction. *Journal of Construction Technology*, v. 10, n. 1, p. 1-15, 2024.

