



Achieving sustainable construction through the integration of lean construction and ESG: A critical review

Nina Agustin^{1,*}, Raldi Hendro Koester¹

¹ School of Environmental Science, Universitas Indonesia, Central Jakarta, Jakarta 10430, Indonesia.

*Correspondence: nina.agustin@ui.ac.id

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ABSTRACT

Background: With the expansion of construction sector, being environmentally responsible and sustainable has become crucial. Given its significant impact on carbon emissions and resource consumption, the industry is encouraged to adopt approaches that enhance efficiency while addressing environmental, social, and economic concerns. **Methods:** This study employed a systematic review and bibliometric analysis using VOSviewer software to qualitatively examine the alignment between lean construction and the ESG framework in the construction industry. **Findings:** Lean Construction (LC), closely aligned with Sustainability and the Environmental, Social, and Governance (ESG) framework, offers a strategy focused on continuous improvement, waste reduction, and value creation. The integration of LC and ESG can accelerate the achievement of sustainability through waste reduction, resource efficiency, and improved worker welfare and better project governance. The objective of this study was to explore the trends associated with the alignment between these two methods in the world of construction and opportunities for further research development. **Conclusion:** This study conducted through systematic review and bibliometric analysis employing VOS viewer software for qualitative analysis. For future research opportunities there will be many related topics such as design or methodology, waste reduction, sustainable building, circular economy, lean tools and carbon footprint. **Novelty/Originality of this article:** This article lies in its integrated exploration of lean construction and the ESG framework through a systematic bibliometric analysis, offering new insights into their synergistic potential for advancing sustainability in the construction industry.

KEYWORDS: bibliometric analysis; ESG; integration; lean construction; sustainability.

1. Introduction

In recent decades, sustainable development has shown its essentiality due to the increasing awareness of quite worrying environmental issues like climate change, environmental degradation through emissions, effluents, and unsustainable resource extraction (Hasan et al., 2024). These issues are closely related in construction industry. The construction sector accounts for approximately 39% of worldwide carbon output, with 28% attributed to energy consumption in building and 11% resulting from the actual activities (Hamilton, 2021). Consequently, it is essential to adapt sustainable methods in the construction sector which has previously advanced significantly. One of the practices that can be executed is lean construction which is synergized with the implementation of environment social governance.

A methodology that can provide extraordinary results in managing construction projects, where the indicator of the successful project can be seen from the quality that meet

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requirements, project implementation according to the budget and project completion according to the schedule is known as Lean Construction (LC). It also conducted to achieve project goals by reducing waste, increasing efficiency and providing maximum value to customers, thus supporting more sustainable development (Albalkhy & Sweis, 2021). While Environment Social Governance (ESG) is a framework used to assess the impact and sustainability of an organization or project through three pillars, namely environmental, social and governance (Cai et al., 2024). Usually, the implementation of LC and ESG are two separate strategies where the purpose of the LC process is to increase economic value, while ESG is for environmental factors. Through several studies and their applications, it is known that these two concepts are interdependent and have the same basis for minimizing waste, saving costs and increasing work safety (Chen et al., 2024). Therefore, the components in LC can be integrated into ESG to improve and conserve natural resources, economic and environmental growth, and improve performance (Tafazzoli et al., 2020).

The purpose of this study is to obtain an understanding of the integrated implementation of LC and ESG in the construction sector and to find research trend of the combination of these two methods in the world of construction and opportunities for further research development. In implementing the integration of these two methods, not only are the benefits obtained, but there are also challenges that need to be resolved so that the implementation and benefits can be felt optimally.

1.1 The linkage between lean construction, and sustainability

The close interconnection between lean construction and sustainability can be seen from both aims to enhance productivity, minimize waste, and lessen adverse effects within the construction sector, thus supporting sustainable development (Opoku et al., 2024). Some key points that explain the relationship are waste reduction, resource use efficiency, improving quality and value for users, and effectiveness in project management.

Waste reduction, the lean approach aims to minimize waste, which is typically identified in seven areas: producing too much, idle time, transportation, unnecessary procedures, surplus stock, motion, flaws, and the lack of input workers in generating ideas to enhance processes (Awad et al., 2021). This is closely related to spatial design, which plays an important role in supporting waste reduction by designing project layouts that minimize worker travel distances, optimize logistics flaws, and reduce waste due to poor spatial planning (Waheed et al., 2024). Research indicates that in construction processes, lean construction prioritizes the reduction of different forms of waste in construction projects including time, resource, and workforce (Bajjou & Chafi, 2020). This supports the environmental aspect of sustainability by minimizing the exploitation of natural resources and reducing waste from the construction process.

Resource use efficiency, one of the concepts of lean is resource use efficiency. Optimizing material use and reduce waste can be achieved by implementing Last Planner System (LPS) and Just in Time (JIT) (Karaz et al., 2020). The implementation of Last Planner System (LPS) and Just-in-Time (JIT) in LC relies heavily on efficient site layout planning to ensure smooth material and equipment flow, avoid bottlenecks, and support labor efficiency (Kovács, 2020). Spatial design facilitates this by designing a layout that considers time, distance, and ease of access within the project (Aslam et al., 2020). LPS was introduced by Ballard in 2000 as a method to enhance predictability of workflows and work plans by controlling the quality of task outlined in weekly plans. Additionally, it contributed to better workforce efficiency. While LPS utilizes the comprehensive project schedule as a foundational guide, the day-to-day production tasks need to be overseen with a more adaptable strategy that acknowledges the project actual progress (Kudrekodlu et al., 2021). LPS focusses specifically on synergistic planning and operational execution, with the goal of improving project schedules, mitigating risks, and ultimately delivering better results (Lagos et al., 2024).

Originated from the manufacturing sector, Just-In-Time technology highlights the importance of executing every phase of construction at the ideal moment, utilizing the

correct amounts, and employing precise materials, people, and tools (Rashid et al., 2025). The implementation of Just-In-Time (JIT) demands a strict sequential flow, whereby each process is initiated immediately following the completion of its predecessor. JIT facilitates construction efficiency by eliminating non-value-adding activities, minimizing process handovers, and mitigating waste resulting from material shortages, overproduction, or excessive procurement (Strukova et al., 2024). This operational discipline is consistent with sustainability objectives, particularly in enhancing resource efficiency and reducing environmental externalities.

Improving quality and value for users, prioritizes the delivery of customer value by systematically eliminating activities that fail to generate added value. This approach aligns with the social dimension of sustainability, which emphasizes responsiveness to stakeholder needs and expectations wherein construction project is expected to generate long-term societal benefits, such as enhancing housing quality and promoting more efficient infrastructure systems (Shaqour, 2022). Good spatial design improves worker comfort, health, and safety, while producing high-quality buildings that are valuable to end users (Voordt & Jensen, 2023). This supports the social dimensions of sustainability and ESG by considering the well-being of all parties involved in the project (Rosarius & García De Soto, 2021).

Effectiveness in project management, with a collaborative and systematic approach, LC combined with spatial design enables better coordination between stakeholders, reduces design errors, and optimizes the performance of construction workflows for improved productivity (Maraqa et al., 2023). It supports sustainability by ensuring projects run according to plan, avoiding cost and time waste and reducing the risk of negative environmental impacts. With the LC collaborative approach combined with spatial design, stakeholders can work in a more coordinated manner, avoid spatial conflicts, and optimize the work sequence (flow), thereby increasing productivity and reducing the potential for design errors or rework that cause waste (Moradi & Sormunen, 2022).

Conversely, in developed nations like the United States (Demirkesen, 2021), Japan (Wagan, 2024), and the United Kingdom (Adewuni et al., 2024) the integration of lean construction with ESG frameworks has advanced considerably, supported by strong ESG regulations, technology and digitalization, lean as an operational standard, social and environmental impacts are taken into account from the project design phase. Meanwhile, in Indonesia, the implementation of LC and ESG integration is still restricted as LC and ESG are still only partially implemented, limitations in regulations and environmental awareness, supervision concerning social and environmental issues remains inadequate. Therefore, high awareness is needed for the integration can be encouraged more intensively, supported by strong regulations and cultural changes for continuous improvement.

1.2 Environment social governance (ESG)

As an evaluative framework for sustainable development, ESG integrates economic, environmental, social, and governance considerations. It serves as an investment philosophy oriented toward long-term value creation, underpinned by a governance-driven perspective that emphasizes holistic thinking and strategic oversight (Li et al., 2021). The ESG framework encompasses three fundamental dimensions; environmental, social, and governance. These pillars are critical for evaluating a company's sustainability performance, identifying potential risks, and informing strategic improvements (Santana Tovar et al., 2025).

In the environmental dimension, it assesses how an organization or project impacts the environment, including waste management, carbon management, energy efficiency and sustainable use of natural resources (Bezerra et al., 2024). This objective can be advanced through spatial design strategies that incorporate passive design principles, maximizing natural lighting and air circulation while reducing reliance on mechanical cooling and heating, which significantly reduces the carbon emissions of construction projects (Abera, 2024).

From a social perspective, emphasis is placed on the protection of fundamental human rights, ethical labor conditions, employee welfare, community involvement, occupational health and safety, corporate responsibility along diversity and inclusion in the organization (Dong et al., 2023). A safe and ergonomic space layout improves workplace safety and worker comfort, and provide accessibility for all groups, including people with disabilities – in line with the inclusion values in the ESG social pillar.

The governance aspect includes risk management, ethics, transparency and regulatory compliance (Monteiro et al., 2024). These aspects serve as critical benchmarks for assessing organizational performance. Accordingly, a comprehensive understanding of the ESG concept is essential for fostering long-term development aligned with the evolving demands of society.

The principal objective of applying ESG within construction is to foster environmental accountability and encourage sustainable design and operational methodologies throughout the project lifecycle (Kong Yap et al., 2024). In this context, lean construction offers structured process optimization strategies that align with ESG's environmental and social pillars, such as waste minimization, efficient resource allocation, and stakeholder engagement. Complementary to these process-focused approaches, spatial and physical design considerations—such as modular layouts, adaptive reuse potential, and inclusive accessibility—can further reinforce ESG objectives without altering the primary LC-ESG integration framework (Shi et al., 2025). The construction industry is likewise expected to minimize waste generation, optimize recycling and reuse initiatives, and integrate circular economy principles into design decision-making (Baabou et al., 2022). Additionally, construction firms can leverage ESG reports to pinpoint areas where inclusion and diversity policies are inadequately implemented. There is a growing trend toward the integration of economic, environmental, social, and governance strategies within the construction sector (Wagan, 2024).

2. Methods

This study analyzes research trends related to the theme of Integration of LC and ESG for sustainable construction by using Bibliometric Analysis. 156 Scopus articles were obtained through search criteria using the keywords “Lean” AND “Construction” AND “Sustainability” OR “ESG” (Figure 1.).

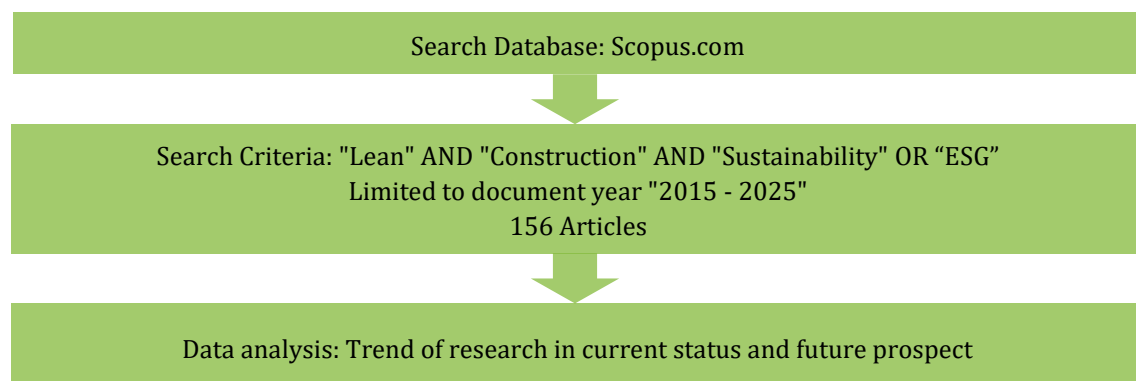


Fig. 1. Stage of bibliometric analysis

From this process, it can be seen that there are not many studies that combine two methods related to lean construction and ESG with only 156 literatures found in a period of 10 years (Figure 2). This could be happened because when analyze about ESG issues in construction, many articles identify ESG with sustainability, so the explanation is not too specific to ESG itself and it could be an opportunity for future research development.

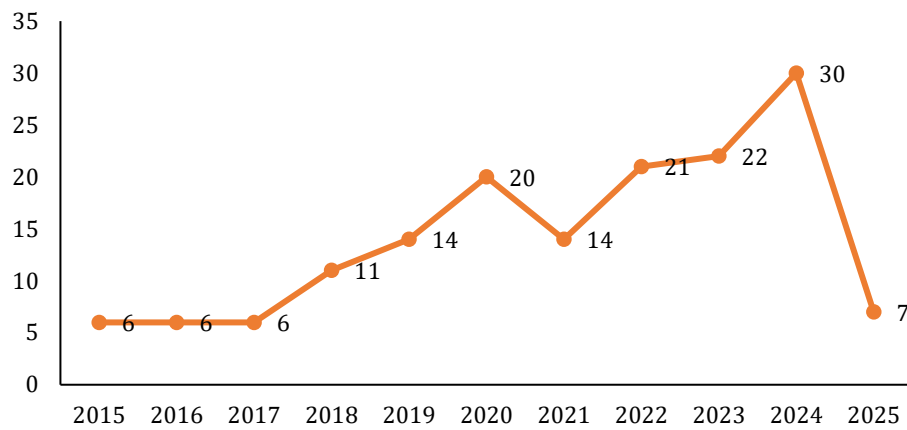


Fig. 2. Publication trends in 2015-2025 on Keywords

3. Results and Discussion

From the range of 2015-2025 and were saved in CSV format and to be reviewed by VOS Viewer for further analysis (Figure 3). From these 156 articles, inclusion was then carried out with the search parameter include document classification “article”, language of publication “English”, source category “journal”, publication status “final”, and 31 documents were obtained for comparative analysis.

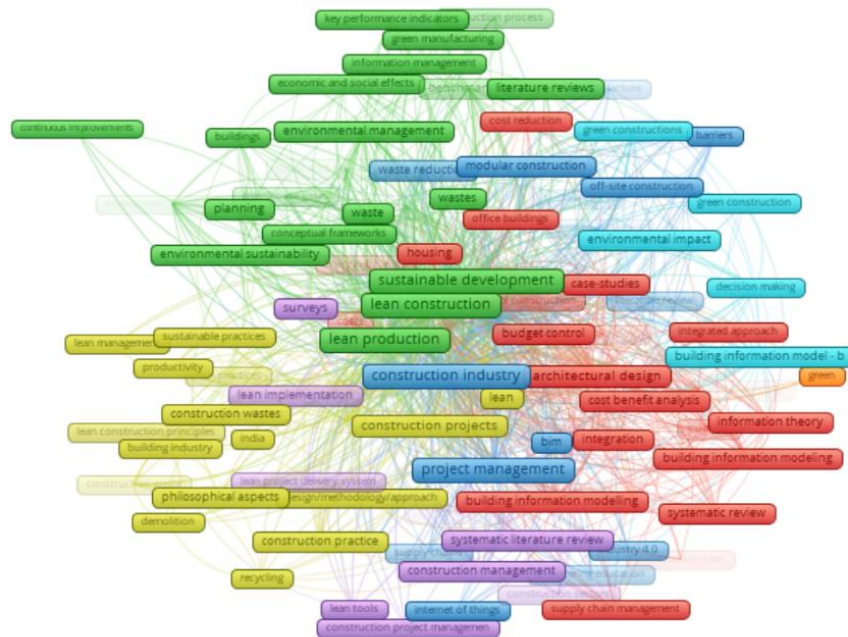


Fig. 3. Co-occurrence map of keywords

An examination of the keyword co-occurrence network enabled the identification of core thematic clusters (distinguish by colour) representative of prevailing research domains, (1) sustainable construction (red); (2) lean construction (green); (3) project management (blue); (4) construction waste (yellow); (5) lean tools (purple); (6) environmental impact (turquoise); and (7) green (orange). The most prominent theme within the green cluster is lean construction, with a frequency of 106 occurrences. This is followed by sustainable development, also within the same cluster, which appears 63 times. This indicates a substantial body of research connecting sustainable development with the construction sector, wherein lean construction is frequently referenced as a strategic

approach to reduce construction waste, thereby enhancing economic sustainability and mitigating adverse environmental impacts (Figure 4).

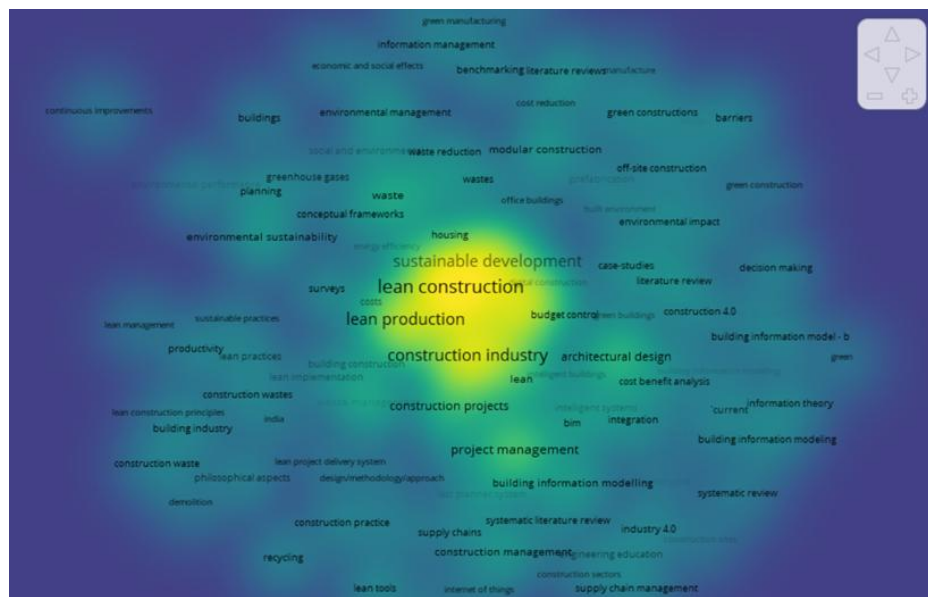


Fig. 4. Co-occurrence density visualization

In the yellow cluster there is also a relationship between construction projects and construction waste. Where waste is a source of inefficiency in a work process that has a great impact on achieving maximum performance. Many methods can be used as research materials in reducing construction waste.

During the 2022–2023 period, core concepts including 'green construction', 'construction waste', 'recycling', 'continuous improvement', 'barriers', and 'integration' have gained prominence, reflecting efforts to advance sustainable construction through innovative and optimization-oriented solutions (Figure 5).

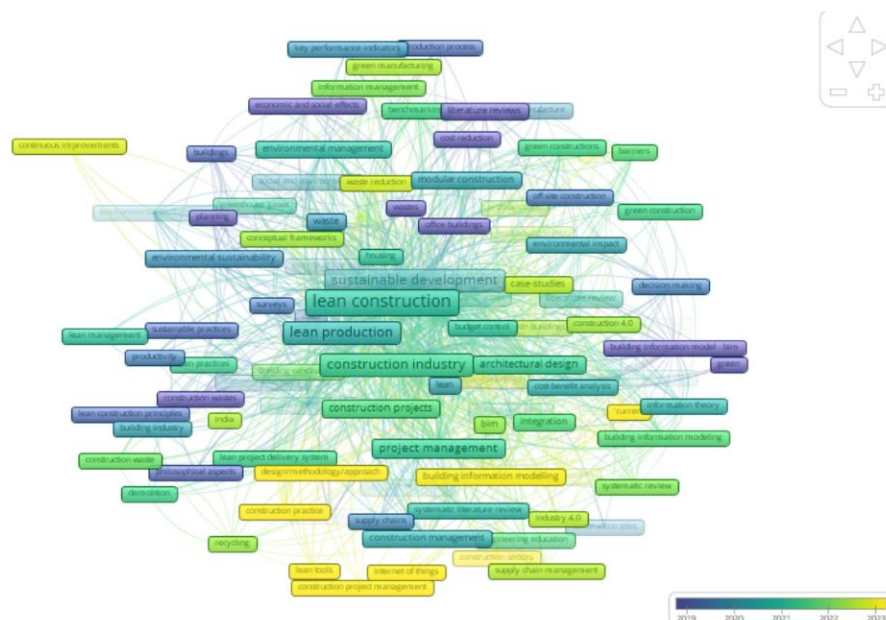


Fig. 5. Co-occurrence per year

The visual analysis suggests that there remains considerable potential for further scholarly exploration, as research on this topic has remained relatively underexplored over the past ten years, such as design/methodology/approach with an occurrence level of 3, sustainable building with an occurrence level of 5, waste reduction with an occurrence level

of 5, lean tools with an occurrence level of 6, circular economy with an occurrence level of 4, and carbon footprint with an occurrence level of 3 (Figure 6). All of these are interrelated in the discussion of sustainable construction.

In terms of design, methodology, or approach, this may encompass various strategies adopted within the construction sector to promote sustainability—such as the application of Building Information Modelling (BIM) (Jing & Alias, 2024; Moradi & Sormunen, 2023) or improving the operational sequence of construction activities. Spatial design plays a pivotal role in optimizing the application of Building Information Modelling (BIM) and improving the operational sequence of construction activities. Through precise spatial modelling, BIM can visualize building layouts, logistics pathways, and the placement of supporting facilities to minimize material transport distances and reduce waiting times in the supply chain (Aksenova et al., 2019).

The concepts of sustainable spans several key aspects, such as optimizing energy performance and incorporating renewable energy technologies, efficient water usage, selection of environmentally friendly materials, and social considerations such as occupant health, comfort, and well-being, as well as building resilience and adaptability to climate change (Abera, 2024). Waste reduction can explain methods to increase efficiency by minimizing waste, both physical and non-physical waste (Waheed et al., 2024). Lean tools refer to specific methods utilized in deploying lean construction methodologies such as the Last Planner System and Just-In-Time (JIT), Value Mapping Stream, Percent Plan Complete and other methods focused on enhancing process flow, and achieving work efficiency (Aslam et al., 2021). Well-conceived spatial design supports lean-oriented work sequencing, enabling the Last Planner System (LPS) and Just-In-Time (JIT) to operate more effectively by optimizing workflow from the design stage. In this regard, spatial design functions as a bridge between lean construction management strategies and digital technology utilization, enhancing process efficiency, minimizing waste, and strengthening interdisciplinary coordination in sustainable projects (Tsegay et al., 2023).

Circular economy in construction can explain the reuse, recycling and extension of the life cycle of materials to reduce waste and environmental impacts with the aim of replacing the linear economic model (take-make-dispose) with a more efficient and sustainable system (Finamore & Oltean-Dumbrava, 2024). Spatial design also strengthens the implementation of circular economy principles in the construction sector (Zhang et al., 2023). Flexible spatial layouts allow future changes in building functions without large-scale demolition, thus extending building lifespans and reducing construction waste (Olynick & Li, 2020). Modular layouts facilitate selective dismantling and reuse of building components, supporting material recycling processes and reducing reliance on virgin resources (Minunno et al., 2020). Moreover, spatial design that accounts for climate adaptability—such as flood protection or improved airflow in hot climates—not only meets sustainability standards but also enhances the resilience of buildings against environmental hazards (Rady et al., 2025). Thus, spatial design operates as a comprehensive strategy that integrates resource efficiency, operational sustainability, and structural resilience (Yao & Zou, 2024).

For the Carbon Footprint theme, it can explain strategies for reducing carbon footprint in sustainable construction (López-Malest et al., 2024). In the context of optimizing energy performance and mitigating the carbon footprint, spatial design contributes through passive design principles such as building orientation to maximize natural daylight, cross-ventilation, and protection against excessive solar radiation (Rady et al., 2025). These strategies reduce dependence on mechanical cooling and artificial lighting, thereby lowering energy consumption and operational carbon emissions. Furthermore, climate-responsive spatial design can accommodate the integration of renewable energy technologies, such as optimally angled rooftop solar panels. This approach aligns with ESG's environmental dimension, which emphasizes minimizing carbon impacts and improving resource efficiency through adaptive and context-sensitive design solution.

There are still many more things that can be raised especially in research on sustainable construction. Themes such as technology integration in sustainable

construction, eco-friendly materials, carbon footprint assessment and mitigation, implementation challenges in developing countries, and policy analysis remain highly relevant, offering valuable direction for future research.

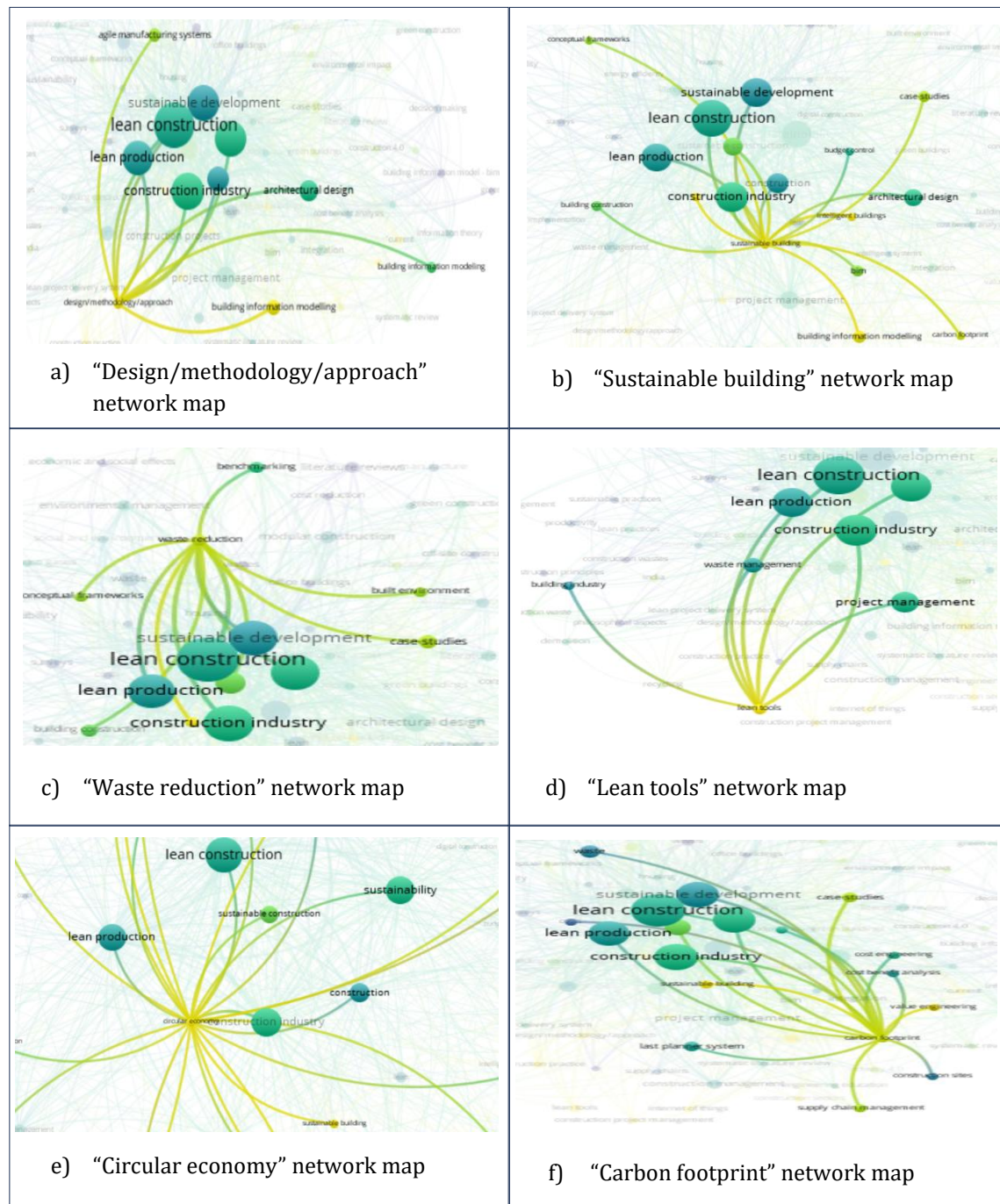


Fig. 6. Future research opportunities

Faria et al. (2023) recognize the construction sector as a principal source of obstacles impeding sustainable development efforts when compared to other sectors. This underscores the importance of clearly defining sustainable construction, which is characterized as the industry's strategic response to sustainability-related challenges (Ershadi, 2021). Its core objective is to minimize the use of materials and energy, thereby reducing pollution and waste throughout all phases of a project (Weerasinghe, 2022). Consequently, the integration of LC and ESG principles is imperative to effectively address these issues.

Embedding LC and ESG principles within construction practices transcends mere efficiency gains and compliance, serving as a pivotal mechanism for progressing Sustainable Development Goals (SDGs). By adopting LC and ESG frameworks, the construction industry can enhance its environmental performance, social responsibility, and overall sustainability, thereby contributing meaningfully to global development objectives and future-oriented impact (Hussain et al., 2019).

This study underscores the significant linkage between the application of LC and ESG frameworks and the attainment of sustainability. Existing literature underscores a wide range of benefits stemming from their integration. Awad et al. (2021) for instance, report measurable advantages including higher productivity, cost reductions, shortened project timelines, and improved sustainability metrics. Likewise, Babalola (2019) emphasize the role of LC and ESG in elevating project quality and operational performance.

A notable example of the effective application of LC and ESG with a focus on waste management is the Eden Project in Cornwall. This project, which features two expansive biomes housing tropical and Mediterranean flora, exemplifies the value of sustainable construction through its adoption of innovative waste management practices throughout its development (Mahdi, 2020). As a renowned tourist destination, The Eden Project underscores the importance of incorporating sustainable waste management into construction projects. The adoption of strategies aimed at reducing waste, reusing materials, and promoting recycling contributed to an impressive 80% decrease in the project's ecological footprint (Ibrahim & Labaran, 2024).

Decreasing the use of unprocessed resources and natural inputs contributes to environmental conservation, lowers greenhouse gas emissions, and reduces the demand for waste disposal infrastructure. Reuse involves identifying construction inputs and outputs that would otherwise be discarded and repurposing them maintained in their initial form or through adaptation for alternative applications (Yu et al., 2021). Recycling, on the other hand, involves converting waste into new materials, thereby diminishing the need for virgin resources and supporting resource preservation. The waste reduction through resource efficiency, reutilization, and reprocessing (3R) strategies within the construction industry fosters more sustainable practices and leads to environmentally responsible outcomes (Tolba et al., 2020).

Beyond process optimization and resource efficiency, certain physical and spatial design considerations can further strengthen the integration of LC and ESG objectives in sustainable construction. Incorporating adaptable spatial configurations—such as modular layouts and flexible floor plans—can facilitate selective dismantling, component reuse, and material recycling, thereby enhancing the effectiveness of 3R strategies without altering the primary process-driven approach of LC (Minunno et al., 2020). Well-planned spatial arrangements also support efficient logistics and on-site workflows, reducing unnecessary material handling and energy use during construction (Xia et al., 2023). Moreover, climate-responsive spatial design—through optimal orientation, natural ventilation, and daylight optimization—complements ESG's environmental dimension by lowering operational energy demand and associated carbon emissions (Mokhtara et al., 2021). These spatial considerations, when embedded early in project planning, function as enablers that enhance the operational impact of LC-ESG integration, contributing to long-term sustainability and improved lifecycle performance.

Another illustrative case is the hospital project in South Australia, named Royal Adelaide, a \$2.4 billion project that demonstrates the successful application of lean construction principles (Ibrahim & Labaran, 2024). The project team implemented the Last Planner System as a collaborative planning tool to enhance project participant coordination and maintain clear, transparent information exchange throughout the project lifecycle. This strategy entailed formulating a comprehensive project timeline that was systematically revised on a seven-day cycle to reflect project progress and maintain alignment to reflect progress and align expectations, incorporating feedback from everyone engaged in the project, particularly those focused on its concluding phases (Francis & Thomas, 2020). The adoption of this method yielded several notable benefits, including enhanced stakeholder

coordination, improved timeline predictability enabling proactive mitigation of delays, reduced construction waste, and overall gains in project efficiency. Furthermore, prefabrication of major hospital components in a controlled manufacturing environment significantly increased workflow efficiency throughout the project lifecycle (Wu et al., 2019). Additionally, the construction project leveraged off-site prefabrication and modular building methods to decrease labour demands on-site as well as reduced material waste while improving the quality of construction significantly. The assembly of major sections of the hospital in a controlled factory setting allowed for greater operational efficiency for the team involved throughout the workflow.

Even though several studies have shown that applying integration LC and ESG principles to the construction industry has significant advantages, it has been adopted insufficiently and ineffectively around the globe. The challenges are still encountered which make the achievement of sustainability construction less than optimal. Toriola-Coker et al. 2021 identify persistent Challenges to achieving sustainable construction include inadequate integration of sustainability concepts in academic curricula and a general lack of stakeholder awareness regarding its importance and a limited understanding of the long-term economic benefits associated with life-cycle cost analysis, the perception of sustainability as a secondary concern, and cultural resistance within the construction industry. Meanwhile, Mohamed (2025) emphasizes high cost of sustainable materials, technological limitations, regulatory gaps and cultural resistance hinder progress. Overcoming these challenges requires policy reforms, enhance stakeholder collaboration, investment in education and technology and raise awareness of efficiency across all lines of construction. From these challenges, it can be a reference for future research in finding designs or methods to improve it both in terms of lean construction and ESG.

4. Conclusions

Bibliometric analysis is a valuable method for guiding research focus, especially in interdisciplinary areas such as lean construction, ESG, and Sustainable Construction. It helps identify current research trends, key contributors, and the evolution of core concepts across regions and time. Through co-authorship and keyword co-occurrence analysis, it reveals patterns of collaboration and thematic relationships, highlighting how ESG is increasingly integrated into lean construction discourse. Bibliometrics also exposes research gaps, such as the limited linkage between ESG and Lean practices or the lack of integrative sustainability models. Tools like VOS viewer provide visualizations that support critical analysis and help researchers build data-driven arguments. Overall, bibliometric analysis offers a systematic foundation to refine research direction and enhance the relevance of scholarly inquiry.

In addition to regulatory strength and process standardization, developed countries often integrate spatial and physical design strategies early in the project lifecycle to reinforce LC-ESG objectives. This includes adaptable layouts that enable modular construction, facilitate selective disassembly, and support material reuse—thereby complementing waste minimization goals central to both LC and ESG frameworks. Moreover, spatial planning that incorporates climate-responsive orientation, natural ventilation, and daylight optimization reduces operational energy demands, directly contributing to ESG's environmental pillar. While these spatial considerations are not a substitute for robust policy and stakeholder engagement, their integration into early-stage design enhances the overall effectiveness of LC-ESG strategies, offering long-term operational efficiency and lifecycle sustainability benefits.

Furthermore, the inclusion of spatial design elements in LC-ESG integration fosters operational efficiency by enabling streamlined material flow and reducing non-value-adding movements on-site, consistent with lean principles. By aligning physical layouts with just-in-time (JIT) delivery and modular construction processes, spatial configurations can minimize bottlenecks, lower on-site storage requirements, and reduce exposure to material degradation. Such design foresight reinforces ESG's governance and operational

dimensions by improving accountability in material handling and ensuring adherence to waste minimization targets throughout the project lifecycle.

Additionally, in the context of developing countries like Indonesia, adopting spatially optimized designs could help mitigate limitations in regulatory enforcement and environmental monitoring by embedding sustainability measures directly into the physical blueprint of a project. For example, designing adaptable building envelopes and multifunctional spaces allows future retrofits without significant demolition, thus extending the asset's lifecycle and reducing the overall embodied carbon. While spatial design alone cannot overcome systemic policy or cultural barriers, its integration into LC-ESG frameworks offers a tangible and proactive measure that complements policy-driven and process-driven approaches, bridging the gap between strategic sustainability objectives and practical implementation on the ground.

Moreover, spatial planning embedded within LC-ESG integration can act as a catalyst for digital innovation, enabling the effective use of tools such as Building Information Modelling (BIM) to optimize spatial configurations for sustainability outcomes. When spatial parameters are incorporated into BIM-enabled lean workflows, it becomes possible to simulate and evaluate environmental performance, construction sequencing, and material logistics before execution. This proactive approach supports the ESG environmental and governance pillars by enabling data-driven decisions, enhancing transparency, and reducing design errors that could lead to costly rework and unnecessary waste.

Finally, the combination of spatially responsive design with LC-ESG strategies offers a pathway toward resilience in the face of climate change and evolving social needs. By designing buildings with adaptable internal layouts and flexible public spaces, projects can respond more readily to demographic shifts, health crises, or changing operational requirements without significant structural overhauls. This adaptability not only aligns with ESG's social pillar by enhancing occupant well-being and inclusivity, but also reinforces lean's continuous improvement ethos by reducing the lifecycle costs associated with major renovations. Integrating such spatial adaptability into LC-ESG frameworks ensures that sustainability is maintained not only at project delivery but throughout the operational lifespan of the built environment.

In conclusion, the integration of lean construction and ESG frameworks represents a strategic and transformative pathway toward achieving long-term sustainability in the construction industry, addressing both environmental performance and socio-economic responsibilities. While lean methodologies provide the process-driven discipline necessary to reduce waste, optimize workflows, and improve cost efficiency, ESG principles ensure that these gains are aligned with broader sustainability goals, including social equity, environmental stewardship, and transparent governance. Spatial design, when subtly embedded within this integration, strengthens these objectives by facilitating resource-efficient layouts, adaptive reuse, and climate-responsive configurations that extend the lifecycle value of built assets. Together, these complementary dimensions offer a holistic approach that not only enhances project delivery but also ensures resilience, adaptability, and meaningful contributions to the Sustainable Development Goals.

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Author Contribution

All authors contributed equally to the conception, research, writing, and revision of this manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

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Biographies of Authors

Nina Agustin, School of Environmental Science, Universitas Indonesia, Central Jakarta, Jakarta 10430, Indonesia.

- Email: nina.agustin@ui.ac.id
- ORCID: N/A
- Web of Science ResearcherID: N/A
- Scopus Author ID: N/A
- Homepage: N/A

Raldi Hendro Koester, School of Environmental Science, Universitas Indonesia, Central Jakarta, Jakarta 10430, Indonesia.

- Email: ralkoest@gmail.com
- ORCID: 0000-0003-1701-0419
- Web of Science ResearcherID: N/A
- Scopus Author ID: 6508263907
- Homepage: <https://scholar.google.com/citations?user=KQN7xg8AAAAJ&hl=id>