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REVIEW

Green Construction Management: Advancing Environmental Performance in Project Delivery

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ABSTRACT

The construction industry is a major contributor to global resource consumption and environmental degradation, highlighting the need for effective management-oriented approaches to sustainability. Although previous studies have mostly focused on green building technologies and evaluation instruments, an increasing trend has been observed towards how construction management has influenced emerging environmental outcomes. The article is also based on a critical synthesis of available literature, and thus it helps to understand the conceptual basis of green construction management and explore how environmental performance comes out of managerial choices made at the planning, procurement, and construction execution phases. The review identifies that environmental performance is multidimensional, and it uses energy consumption, emissions, material efficiency, waste generation, and pollution control, explaining the difficulties in measuring and controlling these effects in fragmented project delivery systems. Specific focus is put on how green management practices relate to the facilitating digital technologies, including Building Information Modeling and data-driven monitoring tools, in facilitating informed decision-making and performance improvement. The critical institutional, organizational, and project-level forces and obstacles in attaining green construction management have also been analyzed in the article. This review gives a consistent picture of how construction management can help to improve environmental performance by incorporating knowledge on managerial practices, technological enablers, and strategic responses. The results provide practical implications for project managers and policymakers and also point to future research directions that will aid in the further development of green construction management concerning sustainable project delivery.

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1. Introduction

The construction industry is one of the basic sectors of economic development, infrastructure, and urbanization in the world[1,2]. It is, however, also well known as one of the most resource-intensive and ecologically affecting industrial sectors[3]. The proportion of construction activities in the total energy consumption in the world, the extraction of raw materials, the production of solid wastes, and greenhouse gas emissions during the lifespan of constructed properties is high. With the ever-increasing concerns about climate change, resource shortages, and ecological degradation, the process of enhancing the environmental performance of construction projects has become a pressing matter for both the governments and the stakeholders in the construction industry and the research community.

Conventionally, the traditional issues of environmental sustainability in construction have been handled through green building design and energy-efficient technology alongside environmental assessment tools implemented at the product or building level. Although such initiatives have produced noticeable improvements, it is increasingly becoming evident that technological solutions cannot help bring about meaningful and consistent improvements in the environment. Construction projects are complex socio-technical systems that are typified by a fragmented supply chain, multi-stakeholder, dynamic site environment, and intense cost-time constraints. Consequently, design decisions do not affect environmental performance in isolation, and the method used to plan, procure, manage, and deliver projects has a great impact on environmental performance. This has put focus on the management aspect of sustainability, and the notion of green construction management (GCM) emerged[4].

Green construction management goes above and beyond the traditional goals of project management to include the consideration of the environment in the decision-making and implementation of the project. It also focuses on incorporating sustainability concepts into the whole project delivery process, i.e., life-cycle thinking, resource effectiveness, pollution prevention, and stakeholder cooperation. From the planning and procurement plans at the early stage through the execution and coordination of the construction activities, GCM aims at inculcating environmental responsibility into the normal management processes, as opposed to incorporating sustainability into construction as an add-on exercise or an obligation[5,6].

Although its relevance is increasing, the literature on green construction management is quite disjointed and lopsidedly developed. The current literature is inclined to investigate separate components, i.e., waste management activities, green procurement strategies, or the use of certain evaluation tools[7]. Although these studies are insightful, they tend to be rather single-clan based in the sense that they fail to give a coherent view as to how managerial practices produce environmental outcomes in the aggregate during project delivery stages. Besides, the conceptual boundaries of the GCM do not necessarily tend to be clearly defined, and thus they overlap with the associated concepts of sustainable construction, green building, and environmental project management. This theoretical vagueness restricts the capacity for theoretical progress as well as the transformation of research outcomes into consistent approaches to management.

The other gap in the existing body of literature is the lack of connection between construction management practices and the quantifiable metrics of environmental performance. Most research focuses on embracing green practices without critically looking at their effectiveness, trade-offs, and interactions with conventional project objectives[8]. An example is that organizational capacity, contractual agreements, or the supply chain dynamic may limit the environmental advantages of some practices. On the other hand, cost-cutting or schedule-cutting managerial decisions can negatively affect environmental performance unless sustainability aspects are embedded into the systems of project deliveries systematically. To deal with such tensions, there is a need to understand more about the role of management structures, decision-making processes, and enabling technologies in practice to bring about environmental outcomes.

The latest development of digital technologies also makes the situation more complicated and richer in the sphere

of green construction management[9]. Building information modeling (BIM), data support systems, and digital monitoring platforms are some of the tools that not only create new opportunities to increase transparency to the environment, but also coordination and performance optimization. Nonetheless, they are largely dependent on management incorporation, organizational preparedness, and stakeholder unionization. In this light, technological innovation should not be considered in isolation, and instead, it should be regarded in association with management practices. The environmental performance of project delivery requires a thorough analysis of GCM to consider both managerial and technological enablers of environmental performance.

Simultaneously, institutional forces, such as increased environmental standards, procurement rules, and directives that are oriented towards sustainability, and the increasing clientele pressure on low-carbon and resource-efficient projects, are transforming the construction business[10,11]. These pressures are significant forces that have driven towards the application of green management practices, but they present new challenges that are based on compliance costs, lack of knowledge, and organizational resistance. It is important to comprehend the interaction of external drivers, internal capabilities, and project-level practices in order to develop GCM in theory and practice.

It is in this context that a thorough and integrative analysis of green construction management is required to integrate the existing studies and clarify major concepts and the possibilities of advancing environmental performance in project provision. Instead of enumerating specific tools or practices, such a review ought to dwell upon the role of management practices in shaping the effect of the environment in the project life cycle and how the management practices will be strategically aligned with the overarching sustainability objectives. Given the fragmented nature and focus on a broadening scope of emerging themes, a review can give a logical basis to new empirical studies and practical applications.

This article aims to critically review and synthesize the literature on green construction management and, in particular, move the environmental performance in project delivery forward. The review looks into conceptual underpinnings, major environmental performance aspects, managerial practices, and facilitating technologies, drivers, and obstacles to GCM implementation. It is through this synthesis that the article seeks to (1) explain the part played by construction management in influencing environmental outcomes, (2) determine the strategic ways in which sustainability can be incorporated into the project delivery processes, and (3) give future research directions that can facilitate further development of green construction management.

This review makes a contribution to the body of literature in construction management and sustainability and provides an insight into the field to practitioners who may want to provide economically and technically successful, yet environmentally responsible projects.

2. Methodology

The article takes a systematic and organized review methodology to integrate the available literature on green construction management and its impact on improving performance in construction projects in terms of environmental conservation. The methodology was discussed in such a way that it should provide transparency, comprehensiveness, and analytical rigor, but should contribute to building an integrative conceptual understanding instead of a purely bibliometric or statistical aggregate of the studies.

2.1. Literature Search Strategy

The literature search was narrowed to peer-reviewed journal articles that were published in international journals associated with the management of construction, sustainability, and the built environment[12]. Large academic databases that are often utilized in research in the field of construction management, including Web of Science and Scopus, were utilized to achieve a wide representation of high-quality publications which are indexed. Search strings were constructed through incremental development by involving the combination of the keywords that related to green construction management, sustainable construction, environmental performance, and project delivery. In order to capture conceptual variations, the same words and similar phrases were incorporated, such as sustainable construction management, green project management, and environmental management in construction.

The search was limited to journal articles written in the English language so that the interpretation and analytical

depth are kept consistent. There was no time limit, but more emphasis was laid on the works that were published within recent years, as they will show the current practices, regulatory environment, and technological changes that have taken place in the construction industry.

2.2. Study Selection and Screening

The preliminary screening was done on the basis of titles and abstracts to eliminate studies that obviously did not concern construction management or environmental performance in delivering projects. Articles that only considered building design, material science, or operational energy performance without the management or project delivery standpoint were omitted. The rest of the articles were separated and then evaluated based on full-text analysis to ascertain their importance toward green construction management practices, environmental performance outcomes, or facilitating organizational and technological mechanisms[13].

Only the studies that explicitly dealt with management-related issues were retained, such as planning, procurement, coordination, site management, decision-making processes, or stakeholder involvement. This process of screening helped guarantee that the end product of the literature was in line with the focus of the article, which is management-conducted environmental performance and not technical-based or product-based solutions.

2.3. Analytical Framework and Synthesis Approach

The analysis of the chosen literature was performed through qualitative content analysis and thematic synthesis techniques. Instead of combining the results statistically, the review aimed at determining common concepts, theoretical positions, and linkages between management practices and environmental performance outcomes. The studies were analyzed based on the conceptualization, methodological perspective, and contributions, which allowed defining the prevailing themes and research gaps.

In order to facilitate the synthesis of concepts, the analysis was organized around four dimensions of analysis: conceptual foundations of green construction management, environmental performance dimensions, green management practices and enabling technologies, and drivers, barriers, and strategic responses[14]. These are the dimensions that informed the organization of Sections 3–6 of the article and helped to develop integrative tables and conceptual figures.

2.4. Reliability and Limitations

In order to improve reliability, there were several rounds of coding and thematic refinement, which aimed at maintaining consistency in interpretation and classification. Comparing themes in different studies mediated subjective bias and enhanced the strength of the synthesis. However, this review is limited in one way or another. There are risks of a lack of geographic diversity due to the exclusion of non-English publications and a lack of relevant insights in industry reports or policy documents, due to the emphasis on peer-reviewed journal articles. Even though these shortcomings exist, the implemented methodology presents a strong base upon which the available knowledge can be synthesized and the understanding of the topic of green construction management in project delivery can be developed.

3. Conceptual Framework of Green Construction Management

3.1. Definition and Scope of Green Construction Management

The concept of green construction management can be seen as an answer to the increasing acknowledgment that it is managerial decisions and organizational processes that have a strong impact on environmental performance in construction projects, and not technological solutions. Generally speaking, the term GCM is used to denote the structured incorporation of environmental factors into construction management procedures during the project delivery process. In contrast to conventional construction management, in which the main concerns of the management are cost, time, and quality, GCM is a system that directly integrates environmental goals, such as resource efficiency, reduction of emissions, minimization of waste, and avoidance of pollution, into the management decisions[15].

GCM is a project life cycle project which includes the planning, coordination of design, procurement, execution of construction, and mechanisms of operation and end-of-life

feedback[16]. It focuses more on taking the initiative in environmental management, whereby the sustainability goals are integrated into the initial project design and updated throughout the implementation process. In this respect, GCM contrasts with traditional forms of environmental management, as most of them tend to be reactive or compliance-oriented. The concepts of environmental performance as a core managerial imperative presented by GCM offer a cohesive point of view within the operationalization of sustainability within construction project delivery. In order to define the conceptual limits of green construction management and demarcate it from other related concepts of sustainability, **Table 1** gives a comparison of its focus, scope, and limitations against the existing solutions in the literature.

Table 1. Conceptual comparison between green construction management and related sustainability-oriented concepts in the construction literature.

Concept	Primary Focus	Scope	Limitations
Green building	Environmental performance of buildings	Design and product level	Limited attention to construction processes
Sustainable construction	Broad sustainability objectives	Life cycle of built assets	Often lacks operational clarity
Environmental management	Regulatory compliance and control	Organizational level	Reactive and compliance-driven
Green construction management	Managerial integration of environmental objectives	Project delivery process	Implementation complexity

3.2. Theoretical Foundations and Analytical Perspectives

The green construction management conceptual basis is based on various theoretical approaches of sustainability science, project management, and organizational studies. Life-cycle thinking is one of the most influential views as it focuses on the analysis of environmental impacts at all the project stages and does not only concentrate on the construction process. Life-cycle thinking also forms the basis of many green management practices through the encouragement of decisions that reduce the overall environmental burdens, even where trade-offs are involved between the stages of the project[17,18].

The other critical theoretical foundation is the triple bottom line framework that views sustainability as the pursuit of environmental, economic, and social goals through a balance[19]. In the GCM framework, this model demonstrates the tensions that are inherent with environmental performance in comparison with the traditional project goals of cost effectiveness and a definitive project schedule. Green construction management tries to solve these tensions by encouraging an integrated decision-making approach that would consider the past and the present value of an environment as well as the present value of a project.

Systems thinking is also instrumental in influencing GCM. Construction projects are complex socio-technical systems that have interdependencies among the stakeholders, processes, and resources[20]. Systems thinking offers a basis for explaining how environmental outcomes are formed as a part of interactions between managerial choices, organizational arrangements, and external institutional pressures. This point of view would be used to justify the fact that individual green actions cannot provide significant environmental changes without being integrated into an organized management system. **Figure 1** shows the conceptual placement of green construction management as a process-based and management-oriented framework bridging sustainability theory and the delivery of construction projects.

3.3. Green Construction Management within Project Delivery Systems

The project delivery systems offer an organizational and contractual environment within which green construction management is carried out[21]. The conventional forms of delivery, like design-bid-build, tend to support this division by distinguishing between design, construction, and operation into distinct stages and contract agents. This fragmentation can interfere with the successful incorporation of environmental goals because decisions made at the initial levels do not necessarily give enough attention to the effects on the downstream environment or constructability limits.

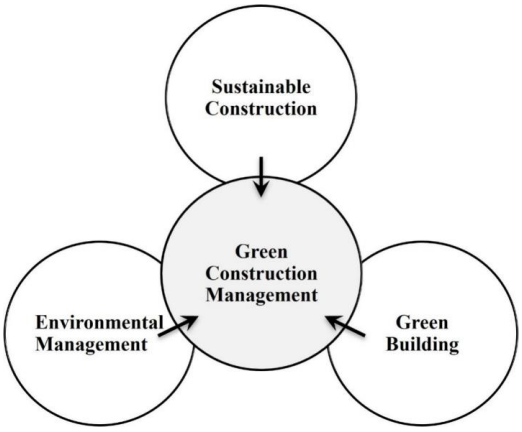

Figure 1. Conceptual positioning of green construction management within sustainable construction and project management research.

More integrated delivery systems, such as design-build and integrated project delivery, in contrast, have more prospects of providing GCM opportunities because of the ability to build collaboration and the early involvement of stakeholders. In these systems, green construction management can help in cross-functional coordination, thus enabling the consideration of the environment in the planning, procurement, and implementation decisions [22]. The earlier the contractor is engaged, such as in the case of green design, the better the construction expertise can guide the green design decisions as to their viability and success.

Green construction management is therefore existing on the border of management activities and project delivery models. Its effectiveness does not merely lie in implementing green practices but also in the alignment of contractual arrangements, communication systems, and incentive systems with the environmental objectives. This alignment is fundamental to the explanation of environmental performance variation among projects and models of delivery [23].

3.4. Core Principles and Managerial Mechanisms

The principles of green construction management are actually interconnected principles, which control the behavior and decision-making of the managers. One of the key principles is resource efficiency, which focuses on minimizing the use of materials, energy, and water by means of appropriate planning, purchasing, and management at the site. This principle is directly connected to the minimization of waste that aims at minimizing construction and demolition waste based on prevention, reuse, and recycling policies and approaches integrated into the management processes [24].

The other major principle is environmental integration, which can be defined as the integration of environmental aims into the daily operations of the management, like planning, cost management, quality management, and risk management. Governmental GCM does not separate sustainability as its own domain and instead promotes managers to take into account both environmental and conventional performance standards. Monitoring and feedback mechanisms help in supporting this integration to ensure that there is constant improvement in environmental performance [25,26].

Shareholder cooperation is another principle behind GCM. The construction projects affect the environmental performance as the activities of various actors, such as clients, designers, contractors, suppliers, and regulators, influence the environmental performance. Green construction management, hence, focuses on the aspects of coordination and sharing of information among the stakeholders in an attempt to align environmental objectives and responsibilities. These mechanisms of management make GCM offer a systematic method of converting sustainability visions into project delivery practices [27].

4. Environmental Performance in Construction Project Delivery

4.1. Environmental Performance as a Project Delivery Outcome

The environmental performance of the construction project delivery is used in reference to the degree to which the project practices reduce the adverse effects on the environ-

ment and contribute to the long-term sustainability goals [15]. In comparison to traditional project outcomes, which are usually measured based on cost, time, and quality, the concept of environmental performance is a multidimensional construct that depends on the managerial decisions made at various levels of projects. It does not exist as an isolated issue in the construction stage but comes as a result of accumulated decisions through planning, design coordination, procurement, and on-site execution.

Project delivery systems influence environmental performance in that they define the distribution of responsibilities, risks, and information that are involved with the stakeholders [28]. Sequencing, resource allocation, and construction techniques and decisions are directly connected to energy usage, emissions, waste generation, and pollution rates. The performance of environmental aspects should therefore be regarded as a result of the project delivery process as opposed to a fixed feature of a completed facility. According to **Figure 2**, the cumulative development of environmental performance in a construction project is based on the management decision-making in the planning, procurement, and construction implementation phases. This process view emphasizes the key role of construction management in the development of environmental outcomes.

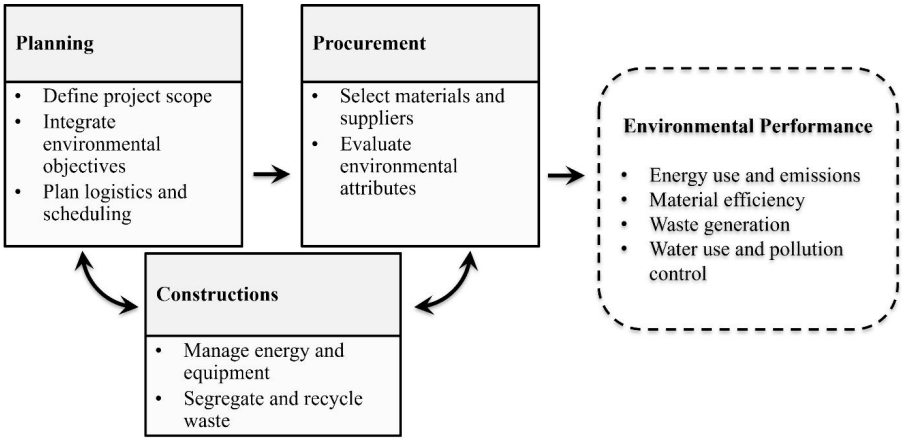

Figure 2. Formation of environmental performance across construction project delivery stages.

4.2. Dimensions of Environmental Performance

Environmental performance of construction projects has various interrelated dimensions that all share the environmental burden of project delivery. One of the most popular dimensions to be studied is energy consumption and greenhouse gases, since it is closely connected to climate change mitigation goals [29]. The use of energy is due to the manufacture of materials, transportation, operation of construction equipment, and temporary facilities on the site, and all these are affected by management practices and logistical planning.

Another important element of environmental performance that is critical is material efficiency and waste production [30]. Construction activities are also significant sources of solid waste materials, especially where ineffective procurement, poor coordination, or re-work has taken place. Management practices that enhance proper estimation of materials, just-in-time delivery, and waste segregation in the field can have a great impact when it comes to waste diversion and resource recovery.

Environmental performance assessment is further widened by the use of water and pollution to the environment [31]. Construction projects use huge quantities of water and may cause air, land, and water pollution. The emission of dust, noise, wastewater release, and chemical runoff are intimately connected with site management approaches, equipment choice, and environmental control systems. A combination of these dimensions indicates the multidimensional aspect of environmental performance in project delivery. **Table 2** summarizes the key performance dimensions and the commonly employed indicators that have been discussed in the literature to present how environmental performance is conceptualized in terms of project delivery.

Figure 3 shows the multidimensional format of environmental performance that connects key categories of impact with indicators that are widely used.

Table 2. Environmental performance dimensions and representative indicators in construction project delivery.

Performance Dimension	Description	Typical Indicators
Energy and emissions	Energy use and greenhouse gas emissions	Energy intensity, CO_2 emissions
Material efficiency	Efficient use of construction materials	Material waste rate, recycled content
Waste management	Reduction and diversion of construction waste	Waste diversion rate
Water and pollution	Water use and environmental pollution	Water consumption, dust, and runoff control

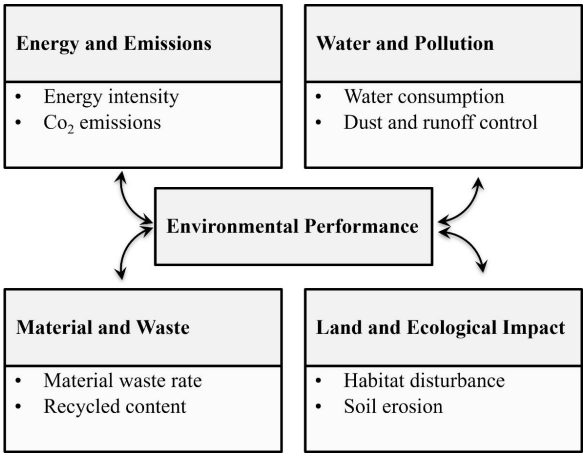

Figure 3. Multidimensional structure of environmental performance and representative indicators in construction projects.

4.3. Performance Indicators and Measurement Challenges

Evaluation of environmental performance in the process of project delivery in construction requires the application of the right indicators, which are able to indicate both the direct and indirect effects. Such indicators are commonly carbon emissions, energy intensity, waste diversion rates, water consumption, and environmental standards or certification compliance[13]. These indicators are measurable indicators, and hence, allow benchmarking and performance comparison within projects.

Measuring environmental performance in construction is, however, a big challenge. The effects on the environment are spread throughout the project stages and supply chains, and there is no way to correlate the results with a particular management activity. Availability and quality of the data are also different, especially in the construction phase, as real-time monitoring of the environmental conditions might not be possible during this stage. Besides, standardized metrics are not always the same everywhere or for all types of projects, and this makes cross-study comparison and synthesis difficult.

The above challenges suggest the significance of environmental measurement, which is the need to incorporate environmental measurement into construction management systems[32]. When performance measures are incorporated into regular planning, monitoring, and reporting procedures, managers can be in a better position to track environmental results and change strategies to achieve them. In the absence of such integration, the environmental performance may be evaluated in a retrospective manner as opposed to being evaluated proactively.

4.4. Trade-Offs and Interactions with Traditional Project Objectives

The issue of environmental performance in the delivery of construction projects is tightly connected with the traditional project goals, which tend to plunge into the trade-offs that the project manager has to maneuver and overcome. In an attempt to enhance environmental performance, there can be increased initial costs, lengthening of timelines, or more planning by stakeholders. Here are a few examples of how it could apply: the use of materials with less impact or a waste reduction plan can be more expensive to procure or more complicated in terms of logistics[33].

On the contrary, when environmental and traditional goals are poorly aligned, it may lead to adverse sustainability. The schedule compression, reduction of costs, or poor coordination can result in additional work, wastage of materials, and energy usage. These relations emphasize the shortcom-

ings of viewing the idea of environmental performance as a separate objective and not as part of the overall project success.

Green construction management aims at resolving these trade-offs through the encouragement of integrated decision-making that will take into consideration the long-term value of the environmental performance. With the environmental goals aligned to cost-efficiency, risk reduction, and quality enhancement, GCM offers a way to reconcile the sustainability goals with traditional project delivery priorities [15,34]. The knowledge of these interactions is critical in both improving environmental performance in construction projects and in coming up with management strategies that can achieve balanced and sustainable results.

5. Green Management Practices and Enabling Technologies

5.1. Green Management Practices across Project Delivery Stages

Green construction management is implemented under various management practices that affect the environmental performance at various levels of project delivery [35]. The formulation of green management practices during the initial planning and coordination phase is aimed at the incorporation of environmental goals into project scope definition, project scheduling, and project resource planning. Site logistics, construction sequencing, and temporary facility decisions can have a profound impact on the energy consumed, emissions, and material efficiency over the project life cycle. Once the environmental aspect is considered at this point, the possibilities of minimizing impact are significantly higher compared to situations when the same is considered at advanced stages of the construction process.

The other key phase of implementation of green management practices is procurement. Environmentally responsible procurement is the choice of materials, equipment, and suppliers not just in terms of costs and availability, but regarding environmental qualities, including embodied carbon, recyclability, and environmental certifications. Reduction of waste, transportation impact, and on-site storage needs can be achieved by management practices that encourage effective communication with suppliers, selecting materials early, and coordinating delivery schedules. These are also applied to ensure that supply chain activities are in line with the overall project-level environmental goals [36].

The site management and operational control are closely related to green management during the construction execution [13,37]. Fuel use and emissions can be cut by efficient use of equipment, an energy-sensitive schedule, and prophylactic maintenance of equipment. Additional benefits to better environmental performance are waste management, such as on-site segregation, reuse of material, and coordination with recycling facilities. The practices need to be monitored and synchronized on a continuous basis, hence the significance of managerial commitment and organizational support towards the realization of environmental goals. **Table 3** depicts the exemplary green management practices for project delivery stages, and how the environmental objectives may be operationalized at each of the stages of planning, procurement, and construction.

Table 3. Green construction management practices across different stages of project delivery.

Project Stage	Management Focus	Representative Practices
Planning	Early integration	Sustainable logistics planning, sequencing
Procurement	Supply chain alignment	Green procurement, supplier evaluation
Construction	Site-level control	Energy-efficient equipment use, waste segregation
Coordination	Process integration	Environmental monitoring and reporting

5.2. Integration of Environmental Objectives into Management Functions

One of the features of green building management is that it involves carrying environmental goals in the usual construction management operations [38]. Instead of making sustainability a concomitant practice, GCM incorporates environmental factors into cost management processes, scheduling, quality management, and risk management procedures. As an example, cost management practices can be used to include life-cycle environmental costs and initial expenditures, and scheduling decisions could take into account en-

ergy efficiency and emissions consequences of alternative construction sequences.

The aspects of quality management at GCM go beyond technical compliance to incorporate environmental performance requirements[39]. This can be an establishment of environmental quality standards for materials, workmanship, and site operation, and also an observance of environmental standards. Equally, environmental-related risks like regulatory non-compliance, pollution events, or damage to reputation are becoming part of project risk management systems. Green construction management boosts the consistency and performance of sustainability initiatives through project delivery by incorporating environmental goals into these functions.

5.3. Role of Digital Technologies as Enablers

Digital technologies have also gained significant importance as facilitators of green construction management by increasing the level of transparency of information, coordination, and decision-making[40]. Building information modeling (BIM) specifically has taken center stage as an avenue through which environmental information can be integrated with project information. Models with BIM allow for visualization and analysis of the amounts of materials, construction processes, and flow of resources, and make more informed decisions regarding the environment during planning and construction.

In addition to BIM, real-time monitoring of environmental performance metrics of energy consumption, waste, and emissions is also supported by data-driven monitoring tools and digital platforms. Such technologies enable project managers to detect environmental target deviations and take corrective measures in a timely fashion. Digital tools also facilitate enhanced communication between stakeholders through the provision of common access to environmental information, and through this avenue, coordination and accountability are enhanced[41].

Nevertheless, the success of digital technologies in aiding green construction management is largely predetermined by the integration of the management as well as the organization's preparedness. In the absence of proper management procedures, training, and motivation, digital tools can either be underutilized or not be linked to environmental goals. Therefore, technologies are to be seen as supplements to, but not substitutes for, good green management practices.

5.4. Synergies between Managerial Practices and Technological Tools

Green management practices and enabling technologies are the best synergy opportunities in enhancing environmental performance in construction project delivery[15]. Managerial practices can give the strategy and the operational framework required to make environmental goals a priority, and digital tools can be used to offer the analytical and monitoring tools necessary to make informed decisions. With a harmonization of these factors, the environmental performance can be planned, implemented, and assessed as part of the project lifecycle.

As an example, digital capabilities can be used to increase the performance of green procurement since they allow the comparison of environmental properties between material choices and suppliers. Equally, site-level management practices can be supported with real-time monitoring technologies that will provide feedback on energy consumption and waste production to improve these practices constantly. These synergies explain the relevance of looking at green construction management as a holistic socio-technical system where managerial and technological elements interact to produce environmental impacts[42].

It is a significant field of future investigations to understand the way those interactions take place in practice. Investigating the joint effect of management practices and digital enablers, researchers and practitioners will be able to define more clearly avenues on how to deliver construction projects with increased environmental performance and long-term sustainability value.

6. Drivers, Barriers, and Strategic Responses

6.1. Institutional and Market Drivers of Green Construction Management

The institutional and market-level drivers that define the organizational behavior and practices in project delivery have a strong influence on the adoption of green construction management. The regulatory frameworks are very critical in the sense that they have been used to set the minimum

performance criteria and compliance levels of construction projects. Ecological policies of emissions, waste disposal, resource efficiency, and environmental impact assessment impose external pressure on organizations to consider the sustainability of the construction management processes [43]. These regulations are getting tougher in most parts, which is why it is necessary to have active environmental management and not passive compliance.

The implementation of green construction management also has some catalysts that are market-driven forces [44]. Increasing customer pressure to have environmentally responsible developments, especially in government procurement and large developments, has pushed sustainability to a competitive advantage. Clients are raising their demands, with an emphasis on the environmental competence of construction firms as evidenced by certified management systems, open reporting, and quantified performance results. Concurrently, industry standard and voluntary certification programs have helped in the proliferation of green management practices because they set benchmarks and send environmental credibility to the market.

6.2. Organizational Capabilities and Stakeholder Influence

At the organizational level, the ability to apply green construction management is based on internal resources, commitment of leadership, and organizational culture [45,46]. Companies that have developed their sustainability programs and have skilled managerial teams are usually at an advantage in incorporating environmental goals in the project delivery. The importance of leadership in setting environmental performance priorities, resource allocation, and a culture that promotes a renewal in sustainability practices is critical.

The effectiveness of green construction management is also defined by the stakeholder influence [47]. There is a wide range of actors in construction projects whose decision-making will all count in the final results regarding the environment. The environmental performance of project delivery involves the designers, contractors, suppliers, and regulators. Stakeholder participation and cooperation are thus critical towards harmonizing environmental goals within the organizational boundaries. Green management practices will be practiced more effectively and consistently when the responsibilities and expectations are clearly communicated.

6.3. Barriers to Implementation at the Project Level

Even with increasing awareness of the management of green construction, there are still major obstacles that have hindered its popularization on a project level. The issue of economic constraints is still eminent, especially when environmental projects are seen to raise initial expenses or to create financial risk or uncertainty. Poor understanding of long-term environmental and economic gains can also be used to enhance opposition to green management practices, particularly in cost-sensitive project setups [48].

Implementation is also impeded by technical and knowledge-related barriers [49]. The construction managers might not have the knowledge needed to assess environmental effects, analyze sustainability information, or incorporate green processes into the existing processes. Fragmented construction project delivery makes the latter issues more challenging because it restricts the sharing of information and coordination between the stakeholders. Also, time constraints and strict contractual agreements might discourage trials of new forms of management, even where the results of environmental benefits are apparent.

6.4. Strategic Responses for Advancing Green Construction Management

The solution to such barriers involves strategic responses that are both organization- and project-based [50]. One of the strategies is the enhancement of institutional support via policy inducements, training schemes, and the propagation of best practices. Funding within the monetary rewards system can be used to mitigate the perceived high cost of green management and encourage investment towards green management capabilities, like tax benefits or special procurement requirements.

On the organizational level, capacity building and knowledge development play a crucial role in entrenching environmental considerations in construction management practices. This involves training the project managers, standardization of environmental practices, and incorporation of the sustainability metrics in the performance appraisal systems. The beneficial avenue of green construction management through collaborative project delivery methods also provides a promising direction for the development of en-

vironmental responsibility and early stakeholder engagement [51,52].

These strategic responses can be used to address the barriers to implementation and improve the effectiveness of green construction management by aligning external drivers, internal capabilities, and practices at the project level [53]. The dynamic interaction of drivers, barriers, and responses is thus important to realize the sustainability aspirations into actual improvements in the environmental performance across the construction project delivery systems. In order to summarize all the above-mentioned multi-level influences, **Table 4** has been made to summarize the key drivers and barriers that influence the adoption of green construction management alongside the corresponding strategic responses.

Table 4. Institutional, organizational, and project-level drivers, barriers, and strategic responses for green construction management implementation.

Dimension	Factors	Strategic Responses
Institutional	Regulations, standards	Policy incentives, enforcement
Organizational	Leadership, capabilities	Training, sustainability integration
Project-level	Cost, time pressure	Collaborative delivery, early involvement
Technical	Knowledge gaps	Digital tools, decision support systems

7. Conclusions and Future Research Directions

This review has critically summarized the fragmented literature on green construction management (GCM) to advance understanding of how managerial practices influence environmental performance in project delivery. The synthesis yields several consolidated insights that represent the cumulative contribution of existing research.

The literature consistently demonstrates that environmental performance in construction projects is fundamentally a managerial outcome rather than merely a technical or design-driven one. Across planning, procurement, and construction execution phases, managerial decisions regarding resource allocation, coordination, sequencing, and stakeholder engagement shape environmental impacts more decisively than discrete technological interventions. This finding challenges the prevailing technological determinism in sustainable construction discourse and establishes GCM as a distinct and essential domain of inquiry. The reviewed studies further reveal that environmental performance is inherently multidimensional, encompassing energy consumption, greenhouse gas emissions, material efficiency, waste generation, water use, and pollution control. These dimensions are interconnected and often involve trade-offs, requiring integrated management approaches rather than siloed interventions. The literature emphasizes that effective GCM must address these dimensions holistically through life-cycle thinking and systems-based decision-making.

The synthesis also indicates that GCM effectiveness depends critically on the alignment between management practices, project delivery systems, and organizational capabilities. Fragmented delivery approaches, such as design-bid-build, consistently impede environmental integration, while collaborative models like integrated project delivery and design-build create more favorable conditions for GCM. This finding underscores that GCM is not merely a set of practices but a function of the broader institutional and contractual environment within which projects are executed. Additionally, digital technologies, particularly Building Information Modeling, real-time monitoring systems, and data analytics platforms, emerge as powerful enablers of GCM, but their effectiveness is contingent upon managerial integration and organizational readiness. The literature shows that technology alone does not produce environmental improvements; rather, it amplifies the impact of sound management practices when embedded within supportive organizational structures and processes.

Despite the growing body of research, the synthesis reveals significant gaps that constrain theoretical development and practical advancement of GCM. First, the majority of existing studies remain descriptive, documenting the adoption of green practices without rigorously establishing causal relationships between specific management actions and measurable environmental outcomes. There is a notable scarcity of quasi-experimental, longitudinal, or intervention-based studies that can isolate the effects of particular management practices from confounding variables. Second, although the literature acknowledges that project delivery systems influence GCM implementation, there is limited comparative

research examining how different delivery models moderate the effectiveness of green management practices. The mechanisms through which contractual arrangements, risk allocation, and communication structures translate into environmental performance remain poorly understood. Third, while digital technologies are increasingly promoted as GCM enablers, few studies examine the organizational and behavioral factors that determine successful technology adoption and utilization. The socio-technical dynamics of how digital tools interact with management decision-making processes constitute a critical but underexplored area. Fourth, the conceptual foundations of GCM remain underdeveloped, with the field drawing eclectically from sustainability science, project management, and organizational theory without establishing a coherent theoretical framework specific to green construction management. This fragmentation limits cumulative knowledge development and impedes the formulation of testable hypotheses.

Based on these identified gaps, several priority directions deserve focused attention in future GCM research. Future research should move beyond descriptive studies to employ rigorous methodological approaches, including longitudinal designs, natural experiments, and structural equation modeling, that can establish causal pathways from management practices to environmental outcomes. Particular attention should be given to mediating and moderating factors, such as organizational culture, leadership commitment, and stakeholder collaboration, that condition these relationships. Systematic comparative research is needed to examine how different project delivery models affect GCM implementation and environmental performance. This should include investigation of contractual innovations, incentive structures, and collaborative mechanisms that facilitate or constrain green management practices across delivery systems. Research should also investigate the organizational and behavioral conditions necessary for effective digital technology integration in GCM, including change management processes, skill development, and decision-support systems that enable project teams to leverage digital tools for environmental performance improvement. Finally, the field would benefit from sustained theory-building efforts based on longitudinal case studies and cross-cultural comparisons. Such research can illuminate how institutional contexts, cultural values, and regulatory environments shape GCM practices and outcomes, contributing to more context-sensitive and generalizable theoretical frameworks.

In conclusion, this review has demonstrated that green construction management represents a vital strategy for advancing environmental performance in project delivery. The accumulated evidence establishes that managerial practices, when strategically aligned with project delivery systems, organizational capabilities, and enabling technologies, can produce meaningful environmental improvements across the construction project lifecycle. However, significant gaps remain in understanding the causal mechanisms, contextual contingencies, and socio-technical dynamics that determine GCM effectiveness. Addressing these gaps through rigorous empirical research and theoretical development is essential for realizing the full potential of GCM. As construction industries worldwide face intensifying pressure to reduce environmental impacts, the insights generated through continued GCM research will be indispensable for guiding practice, informing policy, and supporting the transition toward sustainable project delivery. The construction sector's capacity to contribute meaningfully to global sustainability goals depends, in substantial measure, on the advancement of green construction management as both an academic discipline and a professional practice.

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