Green construction and environmental performance: an assessment framework

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Abstract
Purpose – Construction firms worldwide are increasingly taking pragmatic steps towards addressing environmental problems arising from their activities. Nonetheless, there is a paucity of studies focused on the nexus between green construction and environmental performance. Hence, this study aims to examine the linkages between green construction practice and environmental performance.

Design/methodology/approach – An extensive literature review was conducted to identify the relevant dimensions of green construction practice and indicators for measuring environmental performance. Variables collated were then subjected to pre-assessment and pre-testing processes. The pre-assessment was used as a preliminary content validation where experts assessed the various dimensions of green construction practice and indicators for measuring environmental performance proposed and determine if indeed the variables represent what the study set out to measure. Data were collected from construction professionals within the Ghana’s Kumasi Metropolis. The sample size for the study was 100 experts in sustainable construction methods in the construction industry. A total of 63 responses were received out of the 100 target respondents, accounting for a 63% response rate. Data generated was analysed using mean score analysis and one-sample t-test to determine the level of significance of the various green construction practices and indicators for measuring environmental performance. A Pearson correlation analysis was undertaken to ascertain the relationships that exist among the various dimensions of green construction practice and indicators for measuring environmental performance. Finally, multiple linear regression analysis was utilised to ascertain the effect of the adoption of green construction practice on environmental performance.

Findings – The results indicate that all the green construction practices and the indicators of environmental performance identified from the literature were significant at $p = 0.05$. The study’s findings revealed that energy management is the most significant construct of green construction practice followed by storm-water management. Furthermore, the analysis showed that the preservation of water is the most significant environmental performance indicator followed by sanitation. The regression model developed also explained that 75% of the variations in environmental performance are explained by green construction practice.

Research limitations/implications – Notwithstanding the study’s achievements, one major limitation the research faced was the relatively small sample size.

The project has been financially supported by a grant from the National Research Foundation (NRF), South Africa.
Practical implications – This study provides sufficient data for construction professionals to identify the various green construction practices that could enhance environmental performance. The study's results showed that environmental performance could be improved by adopting the key green construction practices identified in this study. Pragmatic directions are also provided to stakeholders in the construction industry to take a critical look at the environmental performance indicators that were significant.

Originality/value – This pioneering research attempts to investigate the linkages between green construction practice and environmental performance in Ghana. Key results provide a critical evidential influence of green construction on environmental performance and make a crucial contribution to the current body of knowledge.

Keywords Green construction, Environmental performance, Sustainability, Energy management, Waste management, Industry 4.0

1. Introduction

The construction industry significantly contributes to the economic growth and social development of nations (Boadu et al., 2020). Ajayi and Oyedele (2018) proffer that the construction industry is both vital and inextricably linked to the global economy, contributing about 13% to global wealth generation and spurring large-scale employment across the globe. However, the construction industry impacts upon the environment throughout the project’s life cycle, from design through to construction, operation and finally, demolition (Ametepey et al., 2020). Similarly, Nathaniel (2019) reports that the construction industry’s energy consumption and related air emissions negatively impact the environment. This impact has elevated the industry’s sustainability agenda, engendering for the emergence of many environmental concepts worldwide and attempts to develop and apply green practices, such as green construction, green building and green finance (Owusu-Manu et al., 2021).

The construction industry’s environmental impact can be divided into three categories: ecosystem impacts, natural resource impacts and public impacts (Zolfagharian et al., 2014). This industry also consumes vast quantities of energy and concomitant pollution, such as greenhouse gas (GHG) emissions, particulate matter, sulfur dioxide, carbon monoxide and nitrogen oxide (Sandanayake et al., 2019). Because of the sector’s increased energy consumption, the ambient CO2 level has risen, resulting in massive CO2 emissions (Chang et al., 2019). Primary sources of CO2 emissions include the energy necessary for the manufacturing and delivery of building materials and the processing of resources, construction waste management and the demands for construction equipment. Indeed, buildings account for approximately 39% of global CO2 emissions each year (International Energy Agency, 2019). The negative environmental repercussions of global construction activities have promoted the notion of sustainable development (Oke et al., 2019; Fathalizadeh et al., 2021).

The construction industry has aided in bringing together the requirements for green construction to meet the sustainability agenda. Green construction is perceived as a tool for the construction sector to achieve sustainable development (Oke et al., 2019). Several developed countries view green construction as the industry’s response to achieving sustainable development. However, construction projects in many developing countries have been characterized by poor performance in terms of sustainability, going against the call for a more sustainable environment, which is achieved through green construction (Oke et al., 2019). Darabpour et al. (2018) observed that green construction as a sustainability agenda results in environmental protection. Furthermore, the advantages of green construction go beyond reducing the negative impact of construction operations on the environment to boosting productivity (Darko et al., 2017).

With environmental regulations and certification failing to reduce pollution, questions have arisen in developing countries about whether green practices adopted in the construction sector achieve environmental goals (Yusof et al., 2020). Consequently, this
study sought to determine the linkages between green construction practices and environmental performance. Associated objectives are to: educate future construction professionals on how to identify the various green construction practices that could enhance environmental performance; reduce the environmental impact of anthropogenic activities; and elicit wider polemic debate as a means of engendering wider and renewed debate on this globally critical phenomenon under investigation.

1.1 Conceptual review of green construction
Green construction emerges as a guiding paradigm that safeguards the environment and enables present and future generations to meet their own needs (Ametepey et al., 2015). Yilmaz and Bakış (2015) define green construction as the application of sustainable construction principles to the building life cycle, from construction planning and execution, through to raw materials processing into building materials, utilization, construction demolition and waste management. Green construction is emerging as a prominent concept that contributes to the achievement of sustainability in built environment development and the reduction of its impact on the natural environment (Yuan, 2012; Ametepey et al., 2015). To fulfill the sustainability agenda, the industry has emphasized the need for green construction. Green construction encompasses issues such as site planning and organization, material selection, recycling and waste minimization and is best characterized as a subset of sustainable development. Green construction incorporates the fundamental themes of sustainable development, embracing merits such as economic profitability, social awareness and environmental responsibility (Yuan, 2012).

The concepts of sustainable construction and green construction are often used interchangeably. However, there are fundamental differences between the two (Berardi, 2011). Green construction considers the social and economic dimensions but mainly focuses on the environmental dimension, whereas sustainable construction covers all three dimensions simultaneously (Susanti et al., 2019). According to Yin et al. (2018), green construction provides a means through which the construction industry can achieve sustainable development. Shurrab et al. (2019) report that green construction has several advantages, including the ability to improve quality of life and customer satisfaction; provide flexibility and the potential to cater for future user changes; provide and support desirable natural and social environments; and maximize resource efficiency. Construction organizations are under an increasing obligation to adopt green principles in their activities and policies (Robichaud and Anantatmula, 2011). The construction sector has risen to the challenge of green practices, despite increased regulatory and commercial pressure to do so (Onubi et al., 2020). Because of the sector’s environmental impact, improving green construction techniques has become a fundamental goal for countries seeking to follow the path of sustainable development (Shurrab et al., 2019).

The construction industry’s enormous energy consumption is well documented worldwide. Vast natural energy resources are consumed annually to power the: manufacturing of building materials; transportation of these materials from manufacturing plants to construction sites; construction and subsequent operation of the building/structure; and demolishing the building/structure, as well as recycling its parts where applicable (Olanrewaju et al., 2020). According to Oguntona and Aigbavboa (2017), buildings in use account for around 50% of the UK’s total energy consumption, with the construction sector accounting for another 5–10%. China’s building industry utilizes roughly 28% of total energy, with that proportion anticipated to climb to 35% in the future (Wang et al., 2014). Other non-CO₂ greenhouse gas emissions, such as halocarbons, chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs), are emitted heavily by buildings (Pearce and Ahn, 2017). To address this, the construction sector and stakeholders
within it (e.g. architects, contractors, clients and engineers) must be reinvented, with inspiration drawn from nature. Consequently, stakeholders are turning to nature’s magnificent forms of natural energy production, digital solutions, processes and policies for solutions to the world’s countless sustainability concerns (cf. Newman et al., 2020; Iqbal et al., 2021).

According to the United Nations, more than half the world’s population lives in metropolitan areas that are impacted by sprawling urbanization. The volume and maximum discharge of urban floods rise as the permeable urban area is lowered through infrastructure expansion (Wang et al., 2019). Water scarcity is a reason to include an environmental landscape system in urban management frameworks to ensure long-term water supply sustainability. A novel urban rainwater management concept could include developing a hybrid system for landscape restoration and storm-water management. To completely actualize a sustainable environment, the construction of a restoration system that can combine storm-water management activities is a vital step. Ren and Khayatnezhad (2021) observed that China’s government has begun developing an environmental landscape system plan to address the drought in urban water supplementation.

Material waste produced by construction activities (such as concrete, timber or steel) represents the most significant physical waste generated by construction activities. Material waste has a major impact on project costs and has a deleterious impact on the natural environment (Othman and Abdelrahim, 2019). Researchers have presented in-depth analyses of the negative consequences of construction activities, which include land degradation, resource depletion, trash generation and various forms of pollution. According to Lu and Tam (2013), among the numerous negative consequences, building trash often accounts for a large proportion of total solid waste, contributing to environmental deterioration. Kucukvar et al. (2014) proffer that construction waste management is crucial for the long-term treatment of building-related construction and demolition waste materials, and recycling of these wastes is quintessentially important to waste reduction. However, because recycling of building and demolition materials is not always a viable option for all waste types, recycling and other waste treatment methods should be backed up by solid decision-making models. Such models would encourage and support the use of recycled items in a variety of ways, including information exchange, technical specifications and policies such as sustainable procurement, market development and market stimulation. According to Knoeri et al. (2011), the two points of leverage for boosting the use of recycled items are (1) improved access to information and (2) development of expert education. Consequently, increased efforts are necessary to educate stakeholders about the technical qualities and environmental performance of the product and existing laws and requirements. Furthermore, improving engineers’ experience with recycled items is aided by the release of more data, improved documentation and reports on reference buildings. Governments should prioritize updating specific legislation and regulations (cf. Park and Tucker, 2016), with a focus on setting mandatory normative standards. Notably, design guidelines should emphasize the environmental characteristics of the construction industry and provide designers with more material sourcing options, resulting in a higher use of recycled materials. Mandatory policies (such as sustainable procurement to meet specific reuse and recycling targets) would encourage both recyclers and builders to invest in waste management solutions (Ghaffar et al., 2020).

1.2 Conceptual review of environmental performance

Environmental performance refers to improvement in environmental compliance, reduced solid and liquid wastes and greenhouse gas emissions and improvement in recycling activities (Fernando and Wah, 2017). Construction companies have sought to guarantee that their operations are not environmentally detrimental. Most of these initiatives are driven by a desire
to safeguard the natural environment and/or to meet the minimum acceptable environmental performance requirements set by local and/or international regulations (Onubi et al., 2019). These construction companies’ efforts have produced inconsistent results. Onubi et al. (2019) added that the diverse results in terms of environmental performance of construction firms have been linked to varying degrees of complexity in construction projects and construction managers using the same procedures, processes and techniques to manage them.

Three essential green practices identified by studies to achieve greater environmental performance during project planning and implementation are: (1) green supply management methods; (2) waste management methods; and (3) responsible consumption (Lopes De Sousa Jabbar et al., 2017; Martens and Carvalho, 2017; Ajayi and Oyedele, 2018). Yet, until recently, Dragomir (2018) suggests that there was no consensus on how to measure environmental performance. Several studies have used objective measuring indicators such as Rankins Ratings (RKS) and carbon emission figures gathered from secondary data to quantify environmental performance (Hartmann and Vachon, 2017; Shahab et al., 2018). However, Elmagrhi et al. (2018) argue that such metrics are insufficient to adequately depict the delicate character of both the length and breadth of environmental activities. To clarify environmental performance, Hartmann and Vachon (2017) advocated employing latent items and factors. Arimura et al. (2016) use a five-point scale to assess environmental performance, ranging from a significant reduction to a significant increase in natural resource use and air pollution emissions. Yusof et al. (2020) identified energy consumption, pollutant emission and waste reduction and avoiding the use of hazardous materials as common metrics for measuring environmental performance in the construction sector.

The emergence of the sustainable development concept has created more awareness of environmental protection during construction. Hence, environmental performance is regarded as a criterion for assessing project performance (Nilashi et al., 2015). Environmental dangers and degradation are the subjects of the environmental category of sustainability. According to Hussain (2011), over-concentration on human demands will result in catastrophic consequences such as global warming, loss of green areas and disintegration of the ozone layer. Because of the increased focus on sustainability, environmental performance has emerged as a critical criterion in determining project success (Onubi et al., 2020).

1.3 Green construction practices and environmental performance
Green construction is arguably the best solution to combatting the continued pollution and negative impacts of development (Hussain et al., 2019). According to Balaban and Puppim De Oliveira (2017), green construction could yield significant benefits in terms of energy and CO2 reduction, cost savings and improved health conditions for building users. Through the development of sustainable technologies, construction stakeholders can reduce the negative effects of constructing the artificial built environment on the natural environment while also improving economic growth and societal benefits through the development of sustainable technologies (Musango and Brent, 2011). Contractors can also achieve greater project performance by embracing sustainability in building through green construction (Willar et al., 2020).

The environmental dimension of construction is concerned with techniques to design, construct, operate and demolish that will reduce negative environmental impacts such as air emissions, waste discharges, water resource use and land use. The environmental feature of green construction aids in the efficient use of resources and the reduction of waste output (Kheni and Akoogo, 2015). Adoption of green construction strategies (such as lean construction) helps to achieve environmental sustainability in construction by minimizing waste generated during construction processes, reducing natural resource consumption and increasing the use of recyclable materials (Oke et al., 2019). Shurrab et al. (2019) postulate that...
green construction places little demand on non-renewable natural resources and more on recycled materials and enables the efficient use of energy and mineral resources. Green construction, according to Zhou et al. (2013) can result in more efficient resource usage and less environmental stress. Because technical advancement is a fundamental driver for the energy sector (such as digital technologies that coalesce under the banner of Industry 4.0) (Sepasgozar et al., 2020). There is also efficiency in the use of energy with the adoption of sustainable practices (Onubi et al., 2020). Oke et al. (2019) observed that sustainable methods reduce carbon emissions and damage to the ecosystem. Environmental sustainability has become a major factor in the success of construction projects. Green construction provides environmental sustainability through the sustainable use of renewable resources, conservation of life-supporting systems and minimization of harm to the environment and living things (Yilmaz and Bakış, 2015).

2. Research methodology

The epistemological positioning of this research embraced a positivist philosophical stance, which claims that the social world can be understood in an objective way. Positivist research philosophy postulates that the scientist is an objective analyst, and based on that, dissociates himself/herself from personal values and works independently, contributing to existing theories (Zukauskas et al., 2018). This philosophical stance has been widely utilized within contemporary construction management literature. For example, to assess the clerk of works’ role in delivering quality construction (Hughes et al., 2021); to investigate the antecedents of construction project change (Smith et al., 2021); and to assess the role of the quantity surveyor in value engineering (Spellacy et al., 2020). Hence, the positivist philosophical stance was deemed suitable for the study.

An extensive literature review was conducted to first identify the relevant dimensions (variables) of green construction practice and indicators for measuring environmental performance. Second, the variables were subjected to pre-assessment and pre-testing processes. The pre-assessment was used as a preliminary content validation where experts assessed the various dimensions of green construction practice and indicators for measuring environmental performance proposed and determined whether the variables represent what the study set out to measure (see Figure 1). Two experts in the academic field and four professionals in the construction industry comprising two quantity surveyors and two construction managers with considerable experience in sustainable construction methods were involved in the pre-assessment. The respondents were asked to comment on the variables, add more variables that seemed appropriate and rate their potential for inclusion in the study. The dimensions and indicators were considered for inclusion in the study if at least four of the experts agreed. After conferring with these experts, three dimensions of green construction practice (see Table 1) and three indicators for measuring environmental performance were proposed. A structured questionnaire was then developed based on the proposed dimensions of green construction practice and indicators for measuring environmental performance and distributed to the experts. Each variable was scored based on a five-point Likert scale from 1 for strongly disagree to 5 for strongly agree.

The green construction practices identified from literature that are relevant to this study are presented in Table 1.

The study’s population comprised construction professionals within Ghana’s Kumasi Metropolis. Due to the difficulty in accessing a sampling frame and also obtaining responses from various professionals, the study adopted a snowballing non-probability sampling technique. Initially, respondents were selected based on their knowledge of the topic and their willingness to partake in the study. However, referrals to other interested (and similarly knowledgeable) professionals from these initial respondents were adopted to subsequently
Literature Review

Identification of valid dimensions of green construction practice and indicators for measuring environmental performance

Pre-assessment by six (6) experts

Proposal of three (3) dimensions of green construction practice and three (3) indicators for measuring environmental performance

Design of structured questionnaire based on the proposed dimensions and indicators

One-sample t-test to ascertain the statistical significance of the mean values

Regression analysis

Relationship between green construction practice and environmental performance

Figure 1. Methodology flowchart

### Constructs

<table>
<thead>
<tr>
<th>Constructs</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy management</td>
<td></td>
</tr>
<tr>
<td>Energy savings through improved construction site processes</td>
<td>Yilmaz and Bakış (2015), Agyekum et al. (2021), Onubi et al. (2020)</td>
</tr>
<tr>
<td>Sourcing energy from renewable sources</td>
<td>Yilmaz and Bakış (2015), Macedo et al. (2015), Onubi et al. (2020)</td>
</tr>
<tr>
<td>Use of energy-efficient lamps and appliances</td>
<td>Yilmaz and Bakış (2015), Collins et al. (2017), Onubi et al. (2020)</td>
</tr>
<tr>
<td>Maximum use of natural lighting and cooling systems</td>
<td>Collins et al. (2017), Macedo et al. (2015)</td>
</tr>
<tr>
<td>Storm-water management</td>
<td></td>
</tr>
<tr>
<td>Permeable pavement</td>
<td>Eaton (2018), Onubi et al. (2020)</td>
</tr>
<tr>
<td>Maintaining the natural site topography</td>
<td>Eger et al. (2017), Onubi et al. (2020)</td>
</tr>
<tr>
<td>Green roofs</td>
<td>Lucke and Nichols (2015)</td>
</tr>
<tr>
<td>Rainwater harvesting</td>
<td>Eaton (2018), Onubi et al. (2020)</td>
</tr>
<tr>
<td>Waste management</td>
<td></td>
</tr>
<tr>
<td>Waste recycling</td>
<td>Kheni and Akoogo (2015), Ajayi et al. (2016), Onubi et al. (2020)</td>
</tr>
<tr>
<td>Reuse of construction materials</td>
<td>Yilmaz and Bakış (2015), Ajayi et al. (2016), Onubi et al. (2020)</td>
</tr>
<tr>
<td>Complying with recommended stock-pilling arrangements</td>
<td>Bhhardwaj (2016)</td>
</tr>
<tr>
<td>Just-in-time delivery of construction materials</td>
<td>Ajayi et al. (2016), Onubi et al. (2020)</td>
</tr>
<tr>
<td>Waste reduction</td>
<td>Ajayi et al. (2016), Agyekum et al. (2021)</td>
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</tbody>
</table>

Table 1. Green construction practices
grow the sample frame. The sample size for the study was 100 construction professionals, and data were gathered over the course of two months through a face-to-face survey. The 100 survey questionnaires distributed resulted in a 63% response rate. According to Davidoff et al. (2002) cited in Debrah et al. (2020), a response rate of 60% is considered adequate, acceptable or marginal; 70% is reasonable or preferable; 80% is desirable or good, and 90% is excellent in surveys. Hence, a response rate of 63% was considered acceptable for this study.

The statistical analysis employed included mean score ranking, one-sample t-test, correlation and regression analysis. The mean score ranking was used to determine the central tendency of the various green construction practices and the various indicators of environmental performance. A one-sample t-test was used to ascertain the statistical significance of the mean values relating to the various green construction practices and indicators of environmental performance. A correlation analysis was performed to investigate the relationships that exist between the dimensions of green construction practices and indicators of environmental performance. In addition, regression analysis was performed to ascertain the percentage variance in environmental performance caused by the adoption of green construction practices.

Table 2 shows the respondents’ demographic profile. Quantity surveyors made up 43% of the total number of responses retrieved, project managers made up 19%, architects made up 8% and site engineers made up 30%. With regards to the respondents’ educational backgrounds, 49% possessed bachelor’s degrees; 46% possessed masters’ degrees, and the remaining 3% had PhD degrees. This suggests that the respondents were well-educated and had the necessary knowledge required responding to the questionnaire. In terms of professional experience, 29% had one to five years’ experience; 33% had six to ten years’ experience; 22% had eleven to fifteen years’ experience, and 13% had sixteen to twenty years’ experience, while the remaining 3% had over twenty years’ working experience.

3. Data analysis and discussion of results

3.1 Green construction practices

From the desk survey, the study identified three dimensions of green construction practice viz: (1) “energy management”; (2) “storm-water management”; and (3) “waste management”.

<table>
<thead>
<tr>
<th>Profession</th>
<th>Frequency</th>
<th>Percent</th>
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<tbody>
<tr>
<td>Quantity surveyors</td>
<td>27</td>
<td>43</td>
</tr>
<tr>
<td>Project managers</td>
<td>12</td>
<td>19</td>
</tr>
<tr>
<td>Architects</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>Site engineers</td>
<td>19</td>
<td>30</td>
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<table>
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<tr>
<th>Years of experience</th>
<th>Frequency</th>
<th>Percent</th>
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<tbody>
<tr>
<td>1–5 years</td>
<td>18</td>
<td>29</td>
</tr>
<tr>
<td>6–10 years</td>
<td>21</td>
<td>33</td>
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<tr>
<td>11–15 years</td>
<td>14</td>
<td>22</td>
</tr>
<tr>
<td>16–20 years</td>
<td>8</td>
<td>13</td>
</tr>
<tr>
<td>Over 20 years</td>
<td>2</td>
<td>3</td>
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<table>
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<tr>
<th>Academic qualification</th>
<th>Frequency</th>
<th>Percent</th>
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<tbody>
<tr>
<td>Bachelor’s degree</td>
<td>31</td>
<td>49</td>
</tr>
<tr>
<td>Master’s degree</td>
<td>29</td>
<td>46</td>
</tr>
<tr>
<td>Doctoral degree</td>
<td>3</td>
<td>5</td>
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</table>

Table 2. Demographic data of respondents
The mean score rankings of the variables under each dimension are displayed in Table 3. The variables are arranged in descending order of mean, with the highest mean being ranked first and the next highest following suit chronologically under each dimension. When two or more variables have the same mean, the one with the lowest standard deviation is given the highest importance in terms of ranking. Analysis conducted revealed that all the variables had a standard deviation of <2.000, hence indicating and confirming that the survey respondents clearly interpreted all the variables analogously. It can be deduced that under energy management, the highest variable which the respondents agreed to be contributing to green construction practice is the maximum use of natural lighting and cooling systems (with a mean value of 4.52 and a standard deviation value of 0.669). The second highest variable was energy savings through improved construction site processes, which had a mean value of 4.46 and a standard deviation value of 0.692. The third ranked variable under energy management was the use of energy-efficient lamps and appliances (a mean value of 4.43 and a standard deviation value of 0.689). The findings under the energy management dimension conform to what researchers agreed to be a significant paradigm in promoting green construction practices (Agyekum et al., 2021; Yılmaz and Baksı, 2015).

Inferring from Table 3, under the storm-water management dimension, the most significant variable which leads to the realization of green construction practice is the use of green roofs; obtaining the highest mean value of 4.25 and a standard deviation value of 0.671. Rainwater harvesting and permeable pavement were all considered as important paradigms in the storm-water management dimension recording mean values of 4.19 and 3.92, and with standard deviation values of 0.737 and 0.921, respectively, as presented in Table 3. The last dimension is waste management. Under waste management, the highest ranked variable is the reuse of construction materials. This variable was ranked first with a mean value of 4.17 and a standard deviation value of 0.752. The second and third ranked variables under this dimension were reduction of waste and recycling of waste (4.14 and 4.13 as the mean values, 3.92 as...
respectively), with their standard deviation values being 0.737 and 0.793, respectively. Based on the one-sample \( t \)-test analysis at 95% confidence level, a variable with a mean score > or equal to the anticipated mean of 3.0 was considered significant.

### 3.2 Environmental performance

Respondents’ perceptions of the indicators of environmental performance were ranked using mean score ranking as shown in Table 4. The indicators for measuring environmental performance were categorized into three thematic groupings viz.: “air quality” (five variables), “water” (three variables) and “sanitation” (three variables). The various indicators were ranked under the categories and the overall ranking. The most significant indicator was “water”, with a mean score of 4.38, as presented in Table 4. Under this category, “optimization of the consumption of clean water” [mean = 4.44 and standard deviation = 0.667], “access to improved water for all” [mean = 4.38 and standard deviation = 0.633] and “preserving water resources” [mean = 4.33 and standard deviation = 0.718] were the highest ranked variables, ranking first, second and third, respectively. The second-ranked category for measuring environmental performance was “sanitation”, with a mean score of 4.36. As presented in Table 4, “minimizing waste generation” [mean = 4.52 and standard deviation = 0.618], “maximizing the variation of waste through composting” [mean = 4.33 and standard deviation = 0.568] and “recycling and reusing” [mean = 4.22 and standard deviation = 0.750] were ranked by the respondents as 1st, 2nd and 3rd respectively.

Inferring from Table 4, “air quality” ranked as the third most significant environmental performance indicator with a mean score of 4.17. “Reduced air temperature” [mean = 4.43 and standard deviation = 0.734], “low concentration of particular matter in the air” [mean = 4.38 and standard deviation = 0.705] and “CO\(_2\) reduction target” [mean = 4.14 and standard deviation = 0.800] ranked first, second and third respectively, as the most significant variables under the “air quality” indicator.

![Table 4](image-url)
3.3 Correlation analysis
To investigate the relationship between the dimensions in a multivariate analysis, correlation analysis was required (refer to Table 5). This was established by correlating three dimensions of green construction practices, namely “environmental management”, “storm-water management” and “waste management”, as well as three indicators of environmental performance. The confidence interval (CI) of a statistic is regarded as a range of values, calculated from sample observations, that is likely to contain the true population value with some degree of uncertainty (Hazra, 2017). Although the 95% CI is by far the most commonly used, it is possible to calculate the CI at any given level of confidence, such as 90% or 99%. Hence, the choice of a 99% CI for this study; where ** denotes that the correlation is significant at the 0.01 level (2-tailed). From Table 5, it can be deduced that energy management has a positive relationship with air quality, water and sanitation, with Pearson correlation values of 0.544**, 0.628** and 0.363** respectively. All of these were statistically significant, with p-values of 0.01. This demonstrates that energy management has a positive relationship with environmental performance, implying that the adoption of sound energy management practices as a green construction practice will have a positive influence on the environment. The correlation analysis results also reveal that construction waste management has a strong positive relationship with air quality, water and sanitation with Pearson correlation values of 0.763**, 0.488** and 0.572** respectively. These were all statistically significant with p-values 0.01, indicating that the management of construction waste as a green construction practice has a strong positive influence on the environment. Moreover, it is evident that storm-water management has moderate relationship with air quality, water and sanitation, with Pearson correlation values of 0.474**, 0.245 and 0.429** respectively. These relationships between the various green construction practices and indicators of environmental performance are consistent with the literature, as Zhou et al. (2013) posit that green construction can result in more efficient resource usage and less environmental stress. The findings are also consistent with Onubi et al. (2020), who were of the view that because technical advancement is a fundamental driver for the energy sector, there is also efficiency in the use of energy with the adoption of green construction practices.

3.4 Green construction practices and environmental performance
Multiple linear regression analysis was used to test the multivariate relationships between the various green construction practices and environmental performance. Table 6 presents the model’s summary. It can be deduced that an adjusted $R$-Square value of 0.751 depicts that green construction practice accounts for about 75% of the variance in environmental performance. The independent factors sufficiently explained the changes in the dependent variable statistically ($F = 15.397, p < 0.05$). The Durbin–Watson value of 1.950, which is approximately 2.0, suggests a lesser level of autocorrelation (cf. Nyeche, 2015).

<table>
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<th>AQ</th>
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<tbody>
<tr>
<td>EM</td>
<td>Pearson correlation</td>
<td>0.544**</td>
<td>0.628**</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>SWM</td>
<td>Pearson correlation</td>
<td>0.474**</td>
<td>0.245</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td>0.000</td>
<td>0.053</td>
</tr>
<tr>
<td>WM</td>
<td>Pearson correlation</td>
<td>0.763**</td>
<td>0.488**</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td>0.000</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Table 5. Correlation analysis of constructs

Note(s): **Correlation is significant at the 0.01 level (2-tailed)
3.5 Discussions

The regression analysis revealed that the adoption of green construction practices accounts for about a 75% variance in environmental performance. This shows that the adoption and implementation of green construction practices has a strong relationship with environmental performance. *Ceteris paribus*, the practice of green construction, such as maximum use of natural lighting and cooling systems, energy savings through improved construction site processes, use of green roofs, rainwater harvesting, reuse of construction materials, reduction of waste and recycling of waste, will result in a 75% increase in environmental sustainability.

This finding agrees with Oke et al. (2019) who proffered that the adoption of green construction strategies such as lean construction helps to achieve environmental sustainability in construction by minimizing waste generated during construction processes, reducing natural resource consumption and increasing the use of recyclable materials. Construction industry activities (such as large consumption of natural resources, including energy sources and water) adversely impact the environment in terms of unrecoverable natural resources, waste generation, acid rain and global warming. It is evident that measures are required to make construction activities and the built environment more sustainable (Ametepey et al., 2020). Shurrab et al. (2019) postulate that green construction places little demand on non-renewable natural resources, and more on recycled materials, and enables the efficient use of energy and mineral resources. Because technical advancement is a fundamental driver for the energy sector, there is also efficiency in the use of energy with the adoption of sustainable practices (Onubi et al., 2020). Also, according to Oke et al. (2019), sustainable methods reduce carbon emissions and damage to the ecosystem. Environmental sustainability has become a major factor in the success of construction projects. Green construction provides environmental sustainability through the sustainable use of renewable resources, conservation of life-supporting systems and minimization of harm to the environment and living things (Yılmaz and Bakış, 2015).

Viable solutions may reside in technological advancements that coalesce under the banner of Industry 4.0, which includes: the Internet of things (Ghosh et al., 2020); artificial intelligence (Edwards et al., 2000); sensor-based technologies (Riaz et al., 2017); and blockchain technologies (Bayramova et al., 2021). Such technologies are capable of more effectively managing resource consumption throughout the construction supply chain (from minerals extracted to prefabricated components developed) but also efficiently managing buildings and infrastructure that cumulatively constitute the build environment (cf. Edwards et al., 2017, 2021). While prototypes developed to date have failed to create a holistic smart building environment, the inherent capability of Industry 4.0 technology will continue to shape humanity’s reliance on digital solutions to deliver environmentally friendly built environments that coexist in harmony with the natural environment.

<table>
<thead>
<tr>
<th>Model</th>
<th>$R$</th>
<th>$R^2$</th>
<th>Adjusted $R^2$</th>
<th>Std. error of the estimate</th>
<th>Durbin–Watson</th>
<th>$F$</th>
<th>Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.896$^a$</td>
<td>0.803</td>
<td>0.751</td>
<td>0.235</td>
<td>1.950</td>
<td>15.397</td>
<td>0.000$^b$</td>
</tr>
</tbody>
</table>

**Note(s):** $^a$Predictors: (Constant), Waste reduction, Maintaining the natural site topography, Maximum use of natural lighting and cooling systems, Energy savings through improved construction site processes, Use of energy-efficient lamps and appliances, Sourcing energy from renewable sources, Just-in-time delivery of construction materials, Green roofs, Complying with recommended stock-pilling arrangements, Waste recycling, Permeable pavement, Reuse of construction materials, Rainwater harvesting

$^b$Dependent variable: EP

Table 6. Model summary$^b$
4. Implications of the study
This present study’s significance is measured in terms of the level of its contribution to theory and practice. Theoretically, this study contributes to the growing body of knowledge on sustainability, green construction and climate action, which aligns with the United Nations Sustainable Development Goal 13, which calls for immediate action to combat climate change and its consequences. This study contributes to theories addressing sustainability issues, especially in Ghana and sub-Saharan Africa, by focusing on the relationship that exists between the practice of green construction and environmental performance. The findings stimulate much needed polemic debate on the adoption of green construction practices and the related impacts on the environment. This study will also serve as a source of empirical data to motivate others to conduct further research, such as a qualitative study on the subject.

In addition, this study made a substantial contribution to industry practice and policymakers in the field of green construction practice and environmental sustainability. Specifically, guidelines to policymakers are provided on the shift to green construction towards the resultant achievement of the United Nations Sustainable Development Goals on climate action by 2030. Outcomes of the analysis presented provide stakeholders in infrastructure development an insight into the impacts of the adoption of green construction on the environment. In practice, this study proposes that the concept of green construction can be incorporated into the education and training of stakeholders in infrastructure development, such as non-governmental organizations (NGOs), government agencies and construction firms, to improve the level of awareness of the impact of green construction methods on the environment. Policy implementation should be geared towards reducing unsustainable construction practices and incentivizing sustainable practices.

5. Conclusions, limitations and future work
This study aims to examine the relationship that exists between green construction practices and environmental performance in the construction industry, using the Kumasi Metropolis as a case study. This study presents a novel approach to empirically contributing to knowledge centered on green construction practices and environmental performance in the Ghanaian construction industry. From the review of literature, the study identified three dimensions of green construction practices: (1) “energy management”; (2) “storm-water management”; and (3) “waste management”. The most significant green construction practices under the energy management dimension that were identified from the study were: the maximum use of natural lighting and cooling systems; energy savings through improved construction site processes; and the use of energy-efficient lamps and appliances. The study’s findings also reveal that the most significant green construction practices under the storm-water management dimension were the use of green roofs, rainwater harvesting and the use of permeable pavement. The most significant green construction practices under the waste management dimension that were identified from the study were: the reuse of construction materials; the reduction of waste; and the recycling of waste. The indicators for measuring environmental performance were categorized into three thematic groupings of “air quality”, “water” and “sanitation.” The most significant indicator of environmental performance, as agreed by respondents, was “water” followed by “sanitation” and “Air quality.” A correlational analysis was performed to investigate the relationships between the dimensions of green construction practices and environmental performance in a multivariate analysis. The study revealed that energy management has a positive relationship with air quality, water and sanitation. Also, the correlation analysis results indicate that construction waste management as a green construction practice has a strong positive relationship with air quality, water and sanitation. Moreover, the study revealed that storm-water management has a moderate relationship with air quality, water and sanitation. Multiple linear regression analysis was used to test the
multivariate relationships between the various green construction practices and environmental performance. From the results, it can be deduced that green construction practices account for about 75% of the variance in environmental performance.

Based on the findings, the following recommendations are made viz.: (1) the adoption of environmentally friendly practices by a construction firm plays a critical role in the firm’s success; thus, construction firms and professionals must be environmentally inclined in their operations due to the impact construction activities have on the environment; (2) public awareness of green construction is essential because it leads to the high demand, and consequently, the improved delivery of green construction; and (3) the government should enact strict policies on green construction practices to enhance its implementation. The study results posit that the regulatory environment and support are important factors that influence the tendency of public-sector organizations to initiate and implement green construction practices in construction by organizations. The study also identified the absence of an enabling regulatory environment as the major obstacle to the adoption and implementation of green construction practices in construction by organizations. The implication is that sustainable construction adoption requires the existence of appropriate government policies, procurement laws and regulations. Such policies include promotion of the use of efficient energy materials, waste management, endorsement of low taxes and tariffs on sustainable goods, provision of financial incentives and training programs offered by the government. These policies would aid in the adoption of green or sustainable construction practices, which would lead to the achievement of environmental sustainability. Despite the advances in understanding gained through this research, the study had some limitations. The difficulty in assessing a sample frame, and consequently, a population set raises the question of how representative the sample is? However, the steps taken in conducting this study have reduced the impact of this limitation. Relatively, the sample size was also small. Nonetheless, the level of education and years of experience of the respondents still validate the study’s authenticity for future reference. Further studies can be undertaken on a large set. Future studies can also explore these issues in other African countries to confirm, or otherwise, the study’s findings.

References


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