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Efficacy of Green Operations Management in Achieving Sustainable Construction for Projects in Taguig City

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***Abstract*—Green building practices are increasingly essential in the Philippines to mitigate the environmental impacts of rapid urbanization and address climate change. This study investigates the efficacy of Green Operations Management (GOM) in achieving sustainable construction in Taguig City, Philippines. By analyzing 10 certified green buildings, the research identifies key factors outlined by the BERDE Green Building Rating system and assesses GOM's influence on environmental performance. Through comprehensive statistical analysis, including Pearson correlation and multiple regression, the study reveals significant positive correlations between specific GOM practices, such as waste management, energy efficiency, and indoor environmental quality, and improved environmental performance. Furthermore, the study proposes a Green Operation Management (GOM) model as a strategic tool for construction firms to evaluate and enhance their sustainable performance. The Green Operation Management (GOM) model framework is based on the Life Cycle Assessment (LCA) and construction and maintenance of a green building. By aligning GOM practices with the GOM model, construction firms can achieve a more holistic approach to sustainability. The findings of this study provide valuable insights for developers, regulatory bodies, industry professionals, key stakeholders, and researchers. By implementing effective GOM strategies, the construction industry can contribute to a more sustainable future, reduce carbon emissions, conserve resources, and enhance the overall quality of the built environment.**

Keywords*—Green Building, Green Operations Management, BERDE/ LEED, Sustainable Construction, Environmental Performance.

I. INTRODUCTION

A. Background of the study

In the current generation, construction problems have consistently occurred despite its readiness and preparedness for uncertain events. One of its major issues is the environmental impact of a construction site. Building activities were responsible for 27% of annual emissions, while another 13% came from embodied carbon, which was composed of building and infrastructure materials and construction (Architecture, 2023). Pollution such as noise, air, and even land pollution was sourced from construction areas in Metro Manila. The Department of Environment and Natural Resources-Environmental Management Bureau (DENR-EMB) had initial reports indicating that Metro Manila already exceeded safe requirements in 2022. The Laguna Lake Development

Authority (LLDA) closed down two construction firms in June 2018 for illegally disposing of waste materials and debris in the

Taguig City shoreland region. This was after Environment Secretary Roy A. Cimatu threatened to shut down infraction-prone businesses if they did not follow environmental rules. In August 2020, amidst the pandemic, the Department of Public Works and Highways issued a comprehensive set of construction safety standards. These standards are currently applicable to both public and private infrastructure projects under the Enhanced Community Quarantine (ECQ). In data taken from Numbeo, Taguig City has an air pollution index of 64.58 (high), water pollution of 72.22 (high) and a noise and light Pollution of 63.89 (high). With that being said, it is clear that there should be a solution with the rapid growth of pollution occurring with Taguig City.

Through the application of Green Operation Management (GOM), it can provide a positive outcome in a construction towards environmental safety. This method corporates environmental management practices into production and operations. A 2017 report by the Oxford Business Group (OBG) stated that green construction is essential because buildings' energy consumption impacts human health and the environment. Hence, contributing to the increased growth of global warming. Ensuring that construction activities are carried out in harmony with the environment, conserving the environment in corporate objectives, visions, and goals as well as operation functions, permitting ongoing development, and choosing technology based on sustainability principles.

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B. Statement of the Problem

It was undeniable that the business of construction was one of the most intensive industrial practices affecting the environment all over the world (Gomeseria, 2019). With that said, the country's current massive urban development driven by both its government and private businesses significantly impacted the environment. Thus, the study formulated a systematic process that construction projects can adhere to help in promoting sustainability and mitigating climate change in the field aside from complying with green building policy. However, there were still inadequate cost models, skilled workers, innovative technologies and other compositions of Green Operations Management being applied to achieve Sustainable
Construction. Having inconsistent or irregular sustainable construction and insufficient Green Operations Management methods in Taguig City as gaps found in previous studies, this study aimed to contribute in achieving more sustainable construction through Green Operations Management methods.

C. Objectives

The main objective of this study was to evaluate the efficacy of achieving Green Operations Management in construction projects in Taguig City to promote sustainability. Furthermore, the study aimed to:

1. Identify the critical factors of a successful Sustainable Construction from design, construction, and operations based on BERDE's indicators
2. Establish the efficacy of Green Operations Management in Building's Environmental Performance using Multiple Regression Analysis and Correlation Analysis
3. Devise a method of Green Operations Management applicable to achieving
   Sustainable Construction in Taguig City

D. Significance of the Study

This study would provide valuable insights for multiple sectors within the construction industry, specifically targeting contractors, developers, and engineers. By adopting the proposed methods for Green Operations Management (GOM), these stakeholders can enhance resource efficiency and promote sustainability throughout the construction process. Furthermore, implementing such practices is intended to mitigate the adverse effects of building construction on human health and the environment. This study can also benefit the engineering and architectural sectors by presenting relevant information about the factors of successful sustainable construction. Project managers and workers will benefit from the GOM framework, which details processes that can serve as a guide for building projects. The data collected and analyzed by the researchers would greatly benefit the construction management sector, particularly the Department of Public Works and Highways (DPWH). This study intended to offer insightful information regarding the implementation of various operations, the results of management activities, and the collaboration and involvement of participants. Finally, the findings of this study would be valuable for future researchers as they can enhance the current body of knowledge. This research may serve as a reference and foundation for others conducting similar studies.

E. Scope and Limitations

This study was conducted to analyze the efficacy of Green Operations Management for Sustainable Construction in Taguig, Philippines. The research covered the factors of successful Sustainable Construction which only concerns residential and commercial buildings that were certified by BERDE or LEED for the last ten to fifteen years. Other green building certifications were not used for the analysis of buildings to give focus on the local green building certification and the most widely used certification. Data were obtained only from authorized personnel and engineers assigned in the observed buildings without gathering information from green building organization such as BERDE and PhilGBC. The effect of Green Operations Management in building's environmental performance would be related through the statistical method of Multiple Regression Analysis and Correlational Analysis only. However, differences between GOM and other methods of Multi-Criteria Decision Analysis (MCDA) would not be tackled in this framework. Other construction
operations outside Taguig City were not included within the domain relevant to the study. Moreover, the study aimed solely to develop and propose a framework that addresses the critical factors of GOM, without delving into specific methods and practices of GOM. Consequently, the study focused exclusively on advancing knowledge within Construction Engineering Management, setting aside other disciplines.

II. METHODOLOGY

A. Conceptual Framework

This section identified and categorized variables into dependent and independent variables of this study. In this study, the researchers determined the critical factors based on BERDE's Core Framework as their independent variables. The dependent variables were the gathered environmental performance of the green buildings observed. This produced an analysis of the effectiveness of Green Operation Management (GOM). Additionally, identifying the relationship between GOM and Sustainable Construction created a proposed Green Operation Management (GOM) model, which is based on the sample green building model and Life Cycle Assessment of a building (LCA). That being said, the relationship and proposed GOM model were dependent on the data gathered from feedback from the Taguig City building projects.

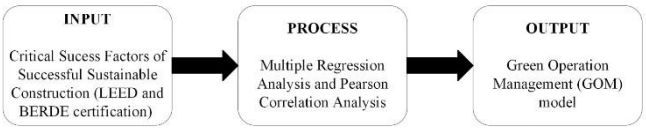


Fig. 1. Conceptual Framework

B. Research Framework

The study's methodology was broken down into four (4) phases. Critical elements for effective, sustainable building were identified in the **first phase** and were included in the design, construction, and operations. This stage described how the data were collected and interpreted in light of the required objectives. It entailed reading and investigating relevant studies that were helpful to the research. In order to gather crucial criteria, researchers simultaneously got in touch with building firms in Taguig. Consequently, a crucial component for a successful building was attained.

In the **second phase**, Green Operation Management (GOM), the crucial elements were assessed. Researchers investigated various evaluation techniques and applied them to the data to produce results from the evaluation and assessment of Green Operation Management (GOM).

The data obtained in this phase were interpreted and analyzed in the **third phase**. Data analysis was done to produce scientific findings for discussion and recommendations. Consequently, identifying the connection between GOM and sustainable construction was the study's second objective.

Building a green Operation Management (GOM) model was the **fourth phase**. This stage aimed to complete the creation of the Green Operation Management (GOM) model, which was the final goal. Researchers created a proposed model that could be employed in Taguig City for sustainable building. Moreover, suggestions and ideas were offered to achieve a unique and interesting outcome. The study's methodology was summarized graphically in a flowchart.

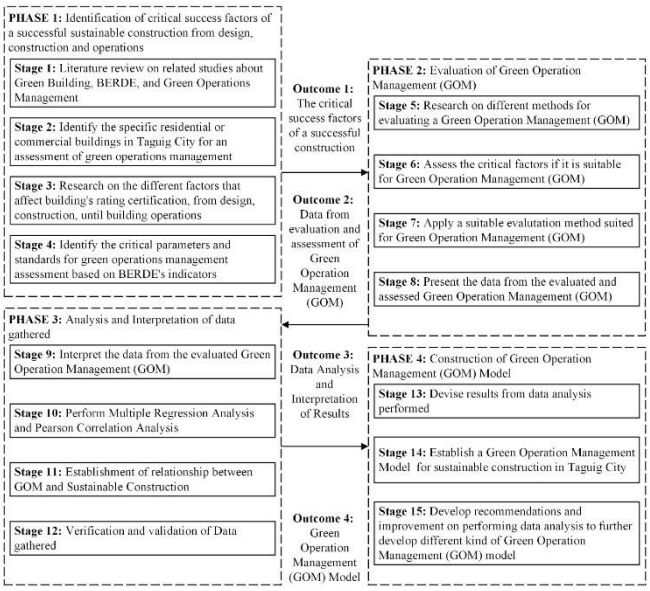


Fig. 2. Flowchart of Methods

C. Research Design

This study was correlational research that utilized a quantitative approach as it aimed to determine the extent of the relationship between Green Operations Management (GOM) and Sustainable Construction through BERDE's rating certification. The study was divided into four phases. The initial phase involved identifying the critical factors of a successful Sustainable Construction, covering design, construction, and operations. The second phase focused on evaluating the Green Operations Management of residential and commercial buildings in Taguig City. Subsequently, the third phase involved the interpretation and analysis of the gathered data. In this phase, the effect of Green Operations Management on a building's environmental performance was established using Multiple Regression Analysis and Correlation Analysis. The concluding phase focused on devising a model based on the data gathered from the initial and secondary phases to create a method for Green Operations Management in sustainable construction.

D. Research Setting

This study was conducted in residential and commercial buildings within Taguig City, Philippines, where several structures have already been certified by BERDE, the local green building rating system. Taguig, known as a green haven, is recognized as a planned city within Metro Manila, promoting sustainable urban development. Specifically, green office buildings in Bonifacio Global City (BGC), Taguig, were assessed based on their green operations and BERDE's green building rating criteria to evaluate, measure, and determine their efficiency in sustainable construction practices.

E. Data Gathering Method

To represent the population of construction projects in the City of Taguig, the study used non-probability sampling, specifically purposive sampling, where a sample of construction firms or developers was chosen based on the researchers' judgment. The study focused mainly on construction projects of residential and commercial buildings managed by developers in Taguig City, such as Arthaland Corporation, Neo Property Management, Inc., Federal Land Inc., and The Net Group. From the selected samples, data were gathered through questionnaires and observations regarding Green Operation Management Methods, along with records from the BERDE rating system. In the first phase of the study, questionnaires were distributed to construction developers, and observations were carried out on their construction practices to collect data on the current Green Operations Management applied in building projects, particularly their priorities, models, and practices. In the subsequent phase, data were gathered from the records of the BERDE rating system on buildings constructed by the examined developers based on the 9 indicators.

F. Data Gathering Instrument

In this study, two key variables were analyzed: the dependent variable, which represents the success of sustainable construction, and the independent variable, which signifies the practice of Green Operations Management (GOM). The relationship between these variables was explored to understand how GOM practices influence sustainable construction outcomes. To effectively measure GOM practices, a structured questionnaire was designed and

distributed to construction managers actively involved in green-certified projects. This questionnaire focused on three main areas: the project priorities related to environmental sustainability, the decision-making models used in managing green practices, and the specific green or sustainable innovations implemented in the construction processes. These aspects allowed for a detailed understanding of the practical applications and impact of GOM within these projects.

To measure the success of sustainable construction, the BERDE Green Building Rating System (GBRS) Version 3.0.0 was used. This rating system, developed specifically for the Philippine context, evaluates buildings across multiple sustainability indicators, such as energy and water efficiency, waste management, materials use, and indoor environmental quality. Each project's BERDE rating was documented, showing its certification level and the scores achieved for various sustainability targets. These ratings provided a standardized metric for gauging the level of sustainable construction success, making it possible to compare performance across different projects.

Rating		Weighting	
★	1 Star	51% ≤ score ≤ 60%	Minimum practice
★★	2 Stars	61% ≤ score ≤ 70%	Good practice
★★★	3 Stars	71% ≤ score ≤ 80%	Ideal performance
★★★★	4 Stars	81% ≤ score ≤ 90%	Exemplar practice
★★★★★	5 Stars	91% ≤ score ≤ 100%	World class

Fig. 3. BERDE Certification Rating and Scoring.

The collected data from the questionnaire and rating system were then analyzed using Multiple Regression Analysis and Correlation Analysis to determine the relationship between the practice of green operations management and the success of sustainable construction.

G. Statistical Treatment and Mathematical Equations

The Pearson correlation coefficient is utilized to measure the linear relationship between two continuous variables, offering insight into how changes in one variable are associated with changes in another. This correlation coefficient, denoted as r, ranges from -1 to 1, where values close to 1 signify a strong positive correlation, values near -1 indicate a strong negative correlation, and values around 0 suggest no linear correlation. The Pearson correlation formula is derived as:

Pearson Correlation:

$$r = \frac{\sum(X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{\sum(X_i - \bar{X})^2} \bullet \sqrt{\sum(Y_i - \bar{Y})^2}}$$

In this context, the variables X and Y represent the datasets being compared, such as performance metrics from hydrological models, environmental parameters, or other statistical outputs. The equation requires the mean values of both X and Y (denoted as $\bar{X}$ and $\bar{Y}$), as well as deviations from these means. These deviations are then squared and summed to form the denominator, while the numerator involves the sum of the product of each deviation pair, establishing a normalized measure of association between the variables. When applied to environmental data, Pearson correlation helps researchers understand the strength and direction of relationships, which can be critical for validating model accuracy or determining influential factors in environmental analysis.

The multiple regression analysis was utilized to determine the relationship between the Environmental Performance and its multiple independent variables which are the 9 core frameworks of sustainable building. The result of R-squared indicates how well the independent variables explain the dependent variable, ranging from 0-1, with 1 implying a perfect fit. The formula for R-squared is derived as:

$$R^2 = \frac{\sum_{i=1}^{n}(\hat{y}_i - \bar{y})^2}{\sum_{i=1}^{n}(y_i - \bar{y})^2}$$

R^2 = R-squared
n = number of observations
y_i = actual values of the dependent variables
$\hat{y}_i$ = predicted values from the regression model $\bar{y}$ = mean of the actual values of the dependent variable

Standard Error stipulates the variability of each coefficient estimate, where values closer to 0 indicate high consistency. P-value quantifies the statistical significance of each variable's coefficient, where a p-value below 0.05 indicates significance. Lastly, coefficients of each factor show the magnitude and direction of each predictor's effect on Environmental Performance, where positive coefficients indicate a positive relationship while negative coefficients indicate a negative relationship. The greater value of coefficients proves a stronger relationship between variables and vice versa. The formula for multiple regression analysis is derived as:

$$Y = b_o + b_1x_1 + b_2x_2 + \cdots + b_px_p + \varepsilon$$

Y = dependent variable
x_n = independent variables
b_o = intercept
b_n = coefficient estimates
ε = error term

However, with the 9 independent variables considered in the study, the process can be lengthy if computed manually. Thus, a computing software, specifically, Microsoft Excel, was used for this step of the analysis.

In Weighted Linear Combination (WLC), each variable (in this case, each green operations management (GOM) aspect) is assigned a weight that represents its relative importance. The weights are derived based on normalized correlation coefficients, reflecting the strength and direction of each aspect's relationship with the overall

GOM score. In Weighted Linear Combination, each aspect's weight W_i is calculated as:

$$r = \frac{Correlation\ Coefficient_i}{\sum Correlation\ Coefficients}$$

where the sum of all weights is 1. By normalizing these weights to sum up to 1 (or 100%), WLC ensures that the final GOM score objectively represents the contribution of each aspect.

III. Results and Discussion

A. Building Characteristics

Bonifacio Global City (BGC), known for its forward-thinking approach to sustainability, served as the ideal study area for analyzing green buildings in the Philippines. This thriving commercial district in Taguig City has earned recognition for its eco-friendly practices and commitment to reducing environmental impacts. With 70% of its office buildings holding certifications from LEED and BERDE, BGC demonstrates a collective effort towards creating a healthier, more sustainable environment. In this study, Bonifacio Global City (BGC) serves as the central hub, where 10 certified green buildings were analyzed to assess sustainable building practices. Below are the characteristics of the 10 green buildings examined in this study.

B. Efficacy of Green Operations Management to Building's Environmental Performance

The summary of data from 10 certified green buildings in Taguig City is presented below, wherein the questionnaire was divided into three parts: GOM applied to the building project, Environmental Performance, and Impact of GOM on the building. The GOM and Environmental Performance were evaluated using a 4-point Likert scale. On this scale, a score of 4 represents "Strongly Agree," indicating the highest level of alignment with sustainable practices and environmental standards in a given category. A score of 3, or "Agree," reflects good compliance with green building standards, signifying that the building meets the requirements effectively, albeit with some room for enhancement. A score of 2, or "Disagree," indicates areas where improvements are needed, as it suggests that current practices and performance only partially meet sustainable benchmarks. Finally, a score of 1, or "Strongly Disagree," points to significant deficiencies, highlighting that the building's operations are not aligned with sustainability goals in that category. This scale allows for a nuanced assessment, capturing the degree of each building's commitment to and effectiveness in implementing sustainable operations and achieving environmental standards. Buildings that score 3 or 4 in the categories are meeting or exceeding the basic sustainable building requirements. A score of 4 suggests optimal practices, while a score of 3 reflects adequate compliance. Scores of 2 or 1, however, indicate areas where a building is not fully aligned with sustainability goals.

1. Green Operations Management

Table 1. Green Buildings' Operations Management Scores.

BUILDING	ENERGY EFFICIENCY	WATER EFFICIENCY	WASTE MANAGEMENT	MANAGEMENT	USE OF LAND AND ECOLOGY	TRANSPORTATION	GREEN MATERIALS	INDOOR ENVIRONMENTAL QUALITY	EMISSIONS	TOTAL GOM SCORE
BLDG 1	4	4	4	3	4	4	4	4	4	35
BLDG 2	4	4	3	4	4	3	4	4	4	34
BLDG 3	3	3	2	2	4	4	3	4	4	29
BLDG 4	4	4	4	4	4	4	4	4	4	36
BLDG 5	3	3	4	3	4	4	4	4	4	33
BLDG 6	4	4	4	3	3	3	4	4	3	32
BLDG 7	4	4	4	4	4	4	4	4	4	36
BLDG 8	4	4	2	2	4	2	4	4	3	29
BLDG 9	3	4	3	4	4	4	2	3	4	31
BLDG 10	4	3	4	4	3	3	4	4	3	32

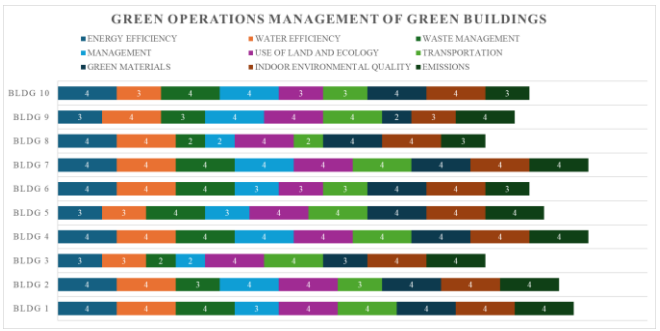


Fig. 4. Graphical Representation of Buildings' GOM.

The green buildings in Table 1 and Figure 4 demonstrate varying levels of excellence in green operations management, as evidenced by their scores across different categories. The table presents the operations management scores of various green buildings. Buildings 4 and 7 stand out as the best-performing structures in terms of green operations management, each achieving the highest possible score of 36. This exceptional performance reflects consistent excellence across all assessed categories, demonstrating a comprehensive approach to sustainability. The achievement of a perfect score also underscores their operational alignment with the highest standards of sustainable building, earning them a 5-star BERDE rating. The consistency in their high scores highlights a well-rounded, balanced approach to green management, setting an industry benchmark and serving as a model for other buildings aiming to achieve sustainability excellence. Buildings 4 and 7 showcase the potential for green buildings to meet and exceed rigorous standards, not only benefiting the environment but also promoting healthier and more efficient spaces.

Building 1 achieved an overall score of 35, earning a Platinum rating under LEED and a 5-star rating under BERDE. This exceptional performance is attributed to its strong scores in all categories, including Energy Efficiency (4), Water Efficiency (4), Waste Management (4), Management (3), Use of Land and Ecology (4), Transportation (4), Green Materials (4), Indoor Environmental Quality (4), and Emissions (4). Following Building 1, Building 2 secured a Gold rating under LEED and a 4-star rating under BERDE, with a total score of 34. While it also excelled in several categories, its scores were slightly lower than Building 1's, particularly in Waste Management and Emissions.

The majority of the other buildings analyzed in the table achieved LEED Gold ratings, indicating a solid commitment to green building principles. Building 3,

Building 5, Building 6, Building 8, Building 9, and Building 10 all achieved LEED Gold ratings, indicating a high level of green building practices. Their scores ranged from 29 to 36, reflecting variations in their performance across different categories. Their scores varied across different categories, highlighting the importance of a balanced approach to green operations management. For example, some buildings excelled in energy efficiency but struggled in waste management, while others demonstrated strong performance in indoor environmental quality but had room for improvement in transportation. The 5-star BERDE ratings achieved by Building 4 and Building 7 are particularly noteworthy, as they indicate exceptional performance in all aspects of green building.

2. Environmental Performance

Table 2. Green Buildings' Environmental. Performance Scores

	QUESTION																							
BUILDING	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	TOTAL SCORE
BLDG 1	4	3	3	4	4	4	4	3	4	4	4	4	4	4	4	4	3	0	4	4	4	3	3	4	86
BLDG 2	4	4	3	4	4	4	4	2	4	4	2	2	2	4	3	4	4	2	4	4	2	3	4	4	81
BLDG 3	2	2	1	3	2	4	0	4	3	2	1	1	4	4	3	4	2	1	4	4	4	4	3	2	64
BLDG 4	4	4	4	4	0	4	0	0	4	4	4	0	4	4	4	4	0	0	4	4	4	4	4	4	72
BLDG 5	4	4	4	4	0	4	0	0	4	4	4	0	3	4	4	4	0	0	4	4	3	3	4	4	69
BLDG 6	4	3	4	3	4	4	0	3	3	3	4	0	3	4	4	4	4	0	4	4	3	3	4	4	76
BLDG 7	4	4	4	4	0	4	0	0	4	4	4	0	4	4	4	4	0	0	4	4	4	4	4	4	72
BLDG 8	2	2	4	2	4	4	0	4	4	4	1	1	3	4	2	4	1	0	4	1	4	3	0	2	60
BLDG 9	3	3	4	3	0	3	0	3	4	4	4	3	3	4	4	4	0	0	4	0	3	3	3	4	66
BLDG 10	4	4	4	3	4	4	3	3	4	3	3	4	4	4	3	4	3	0	4	4	4	3	2	2	80

The summary of results from the Environmental Performance section of the questionnaire was presented in Table 2. Building 1, which obtained the second-highest score for GOM practices, accumulated the highest score of 86 for Environmental Performance. This implies that the GOM practices of the mentioned building are effectively contributing to its environmental performance, given that it has achieved a Platinum LEED Certification. On the other hand, the top scorers in the GOM scores, Building 4 and Building 7, only attained a total score of 72, which is around the average of all scores. With its certifications of LEED Platinum and BERDE 5-star and the results from the previous section, it was less than they are expected to achieve. This must imply that their practices were unsuccessful in meeting the performance standards set in the Green Building Code. Building 2, Building 6, and Building 10 are the subjects that garnered scores higher than the top-scoring buildings. GOM practices may have been efficiently implemented during the design, construction, and operation of the buildings accompanied by their high GOM scores. However, Building 5, Building 9, Building 3, and Building 8 are within the lower percentile of the dataset. Among these, Building 8 acquired the lowest score with only a total of 60. These buildings have not optimized their Environmental Performance through their GOM practices, as reflected in their lower GOM scores. It is also apparent that Questions 5, 7, 8, 12, 17, and 18 have been marked "N/A," equating to 0, more than once within the question pool. This shows that not every building has implemented innovations improving environmental performance, such as insulated roofing, automatic conveyance systems, rainwater harvesting, and sewage treatment plants. While in some cases, performance standards are just not applicable because of the absence of water heating systems and centralized cooling systems. Thus, such a lack compromises environmental standards in terms of water and energy efficiency.

3. Environmental Performance

Table 3. GOM's Impact Checklist Results

BUILDING	BUILDING OVERALL COST	BUILDING SCHEDULE	ENERGY PERFORMANCE	WATER PERFORMANCE	WASTE GENERATION	TOTAL
BLDG 1	1	2	4	5	4	16
BLDG 2	5	4	5	5	5	24
BLDG 3	5	3	4	4	5	21
BLDG 4	5	5	5	5	5	25
BLDG 5	5	5	5	5	4	24
BLDG 6	5	4	5	5	3	22
BLDG 7	5	5	5	5	5	25
BLDG 8	5	4	5	4	3	21
BLDG 9	5	4	5	5	3	22
BLDG 10	2	3	4	4	3	16

Table 3 provides an overview of several key performance indicators related to Green Operations Management (GOM) and their impact on construction projects across various buildings. The metrics evaluated include building costs, schedule impacts, energy and water performance, and waste generation. The 1-5 rating scale used in GOM's Impact Checklist serves as a qualitative measure to assess the impacts of various aspects of construction projects, specifically regarding sustainability practices. A rating of 1 indicates a significantly negative impact, suggesting that the practice or condition has led to increased costs, delays, or adverse effects on energy and water consumption, and waste generation. A score of 2 signifies a slight negative impact, while a 3 denotes no significant impact, indicating that the strategies employed neither improved nor worsened the situation. Conversely, a rating of 4 reflects a slight positive impact, suggesting some benefits, such as decreased costs or improved resource efficiency. Finally, a score of 5 represents a significantly positive impact, demonstrating that the interventions have substantially enhanced the project's performance, including significant reductions in costs, energy use, and waste generation, while potentially expediting project schedules. This scale allows for a nuanced evaluation of how various strategies influence the overall sustainability and efficiency of construction efforts, enabling stakeholders to identify successful practices and areas needing improvement. Moreover, the use of this rating system fosters transparency and accountability among project teams, as it quantifies performance in critical areas of sustainability. Ultimately, the ratings can guide future decision-making and investment in sustainable practices within the construction industry.

The total scores for each building in GOM's Impact Checklist reveal varied performance across the assessed categories of overall cost, schedule, energy performance, water performance, and waste generation. Building 1 and Building 10 both scored the lowest at 16, indicating significant challenges in multiple areas, particularly in overall cost management, where Building 1 received a score of 1—the lowest possible rating, reflecting substantial cost increases. In addition, both buildings displayed weaknesses in waste generation, with Building 10 also showing relatively

low scores across other metrics. Conversely, Building 4 and Building 7 achieved the highest total scores of 25, indicating exceptional performance. The majority of buildings, such as Building 2, Building 5, and Building 6, also performed well, scoring in the mid-20s, but all were outperformed by Building 4 and Building 7.

Building 4 and Building 7 not only topped the list with scores of 25 but also demonstrated the most robust impact of Green Operations Management, reflecting a comprehensive implementation of sustainable practices across all categories. These buildings excelled in energy performance, water management, and waste generation, consistently receiving scores of 5, which signifies significant positive impacts in these areas. This indicates that the strategies employed in these buildings successfully minimized environmental footprints while maintaining or improving project efficiency. The high scores across all metrics suggest that these buildings can serve as models for future construction projects, illustrating the potential benefits of integrating green practices in the construction and operational phases. Their performance exemplifies the effectiveness of strategic sustainability initiatives in achieving both ecological goals and project viability.

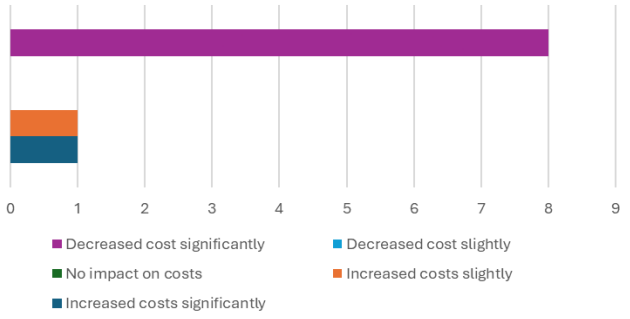


Figure 5. Building Overall Cost.

In Figure 5, 8 out of 10 buildings experienced a decrease in overall costs after implementing green operations management (GOM) practices, which highlights the critical roles of capital expenditures (CAPEX) and operational expenditures (OPEX) in sustainable construction. CAPEX includes the initial costs of incorporating green technologies and sustainable infrastructure, such as energy-efficient HVAC systems, solar panels, or advanced water recycling systems. These upfront investments often raise the initial project costs, where substantial CAPEX for complex sustainability interventions leads to a noticeable increase in overall costs. This increased CapEx is a common challenge for projects aiming for high sustainability standards, as green technologies can be more expensive than conventional alternatives. However, once the upfront investment is made, OPEX—which encompasses the day-to-day running costs like energy, water, and waste management—often decreases due to the efficiency gains from these green technologies. Buildings 1 and 10 may also reflect specific challenges in cost reduction, potentially due to their unique operational demands.

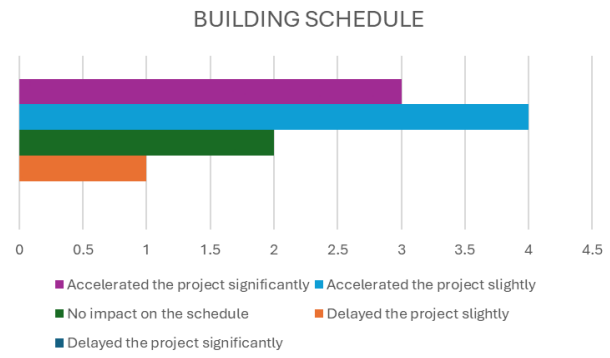


Fig. 6. Building Schedule.

As shown in Figure 6, seven of the buildings experienced accelerated schedules due to GOM practices, implying that the implementation of green strategies may streamline certain processes and reduce delays. This acceleration likely results from several factors integral to GOM, such as advanced planning, better coordination of resources, and the use of sustainable materials that are easier or quicker to install. For instance, green building practices often involve modular components or prefabricated systems, which can be installed more swiftly than traditional materials, reducing on-site labor time and minimizing delays. Two buildings had no impact on their schedule (Building 3 and Building 10), while Building 1 experienced a slight delay, indicating that green initiatives in these cases did not hinder or delay project timelines significantly. For the two buildings with neutral schedule impacts (Buildings 3 and 10), the lack of acceleration implies that green practices did not speed up construction. In the case of Building 1, which experienced a slight delay, it is possible that certain green technologies or design requirements introduced added complexity that required additional time, such as specialized installation processes or the need for specific regulatory approvals.

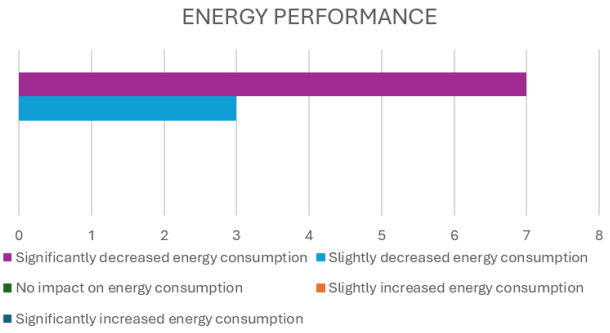


Fig. 7. Building Energy Performance

Figure 7 highlights that all buildings reported either slightly or significantly decreased energy consumption. The fact that 7 out of 10 buildings achieved significant decreases highlights the effectiveness of GOM practices in reducing energy usage. This aligns with the general goals of green building strategies to minimize environmental impact through improved energy efficiency. Key strategies that drove these reductions included the implementation of advanced HVAC systems equipped with smart controls that

optimize temperature and airflow based on real-time occupancy and external conditions, significantly lowering unnecessary energy use. Additionally, energy-efficient LED lighting systems, often integrated with motion sensors or daylight harvesting controls, reduce electricity demand by ensuring lights are only used when necessary. These results highlight the effectiveness of GOM's green building practices in lowering energy use, cutting operational costs, and supporting environmental goals through comprehensive design, technology, and management practices. Further contributing to energy savings were renewable energy sources, such as solar panels, which decreased reliance on conventional power grids by providing clean, on-site electricity.

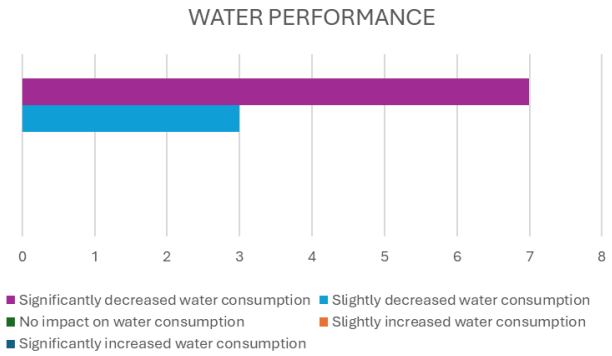


Fig. 8. Water Performance.

All buildings reported a decrease in water consumption in Figure 8, with the majority (7 out of 10) experiencing significant reductions. This further demonstrates the positive environmental impact of green practices, particularly in conserving water—a critical resource in sustainable development. By integrating water-saving technologies and sustainable design strategies, these buildings contribute to environmental sustainability, reduce operational costs, and conserve critical resources. This level of water efficiency aligns well with the goals of sustainable development and underscores the positive environmental impact that green practices can achieve. Through the use of water-efficient fixtures, greywater recycling, rainwater harvesting, smart irrigation, advanced monitoring, and efficient cooling systems, these ten buildings have managed to substantially lower their water consumption, supporting both environmental and economic sustainability goals.

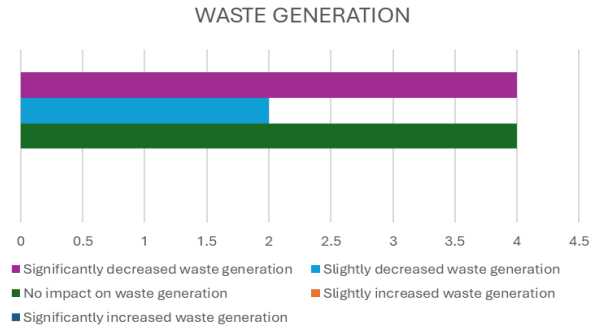


Figure 9. Waste Generation.

Most buildings (6 out of 10) in Figure 9 represent a reduction in waste generation, though some buildings had no impact on waste (Building 6, Building 8, Building 9, Building 10). This suggests that while waste reduction is a priority, its success may vary depending on the specific GOM strategies employed. While there were notable reductions in waste generation, this area showed more variability, suggesting that further focus on waste management strategies could enhance overall performance. The variability in waste reduction performance highlights an opportunity for further emphasis on waste management within green building practices. By strengthening recycling programs, promoting tenant engagement, and employing advanced waste management technology, these buildings can improve their waste reduction outcomes, aligning closer with sustainability goals. These green buildings have made progress in reducing waste generation through recycling, sustainable materials, and on-site processing. However, the mixed results suggest that a continued focus on waste management strategies will be essential to maximize the environmental benefits of green building practices.

Table 4. Weighted GOM Scores.

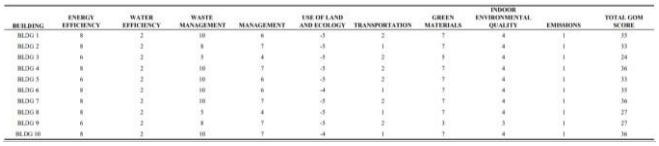


Table 5. Buildings' Ranking Based on Weighted GOM Scores.

RANK	BUILDING	TOTAL GOM SCORE
1	BLDG 10	36
2	BLDG 4	36
3	BLDG 7	36
4	BLDG 6	35
5	BLDG 1	35
6	BLDG 2	33
7	BLDG 5	33
8	BLDG 9	27
9	BLDG 8	27
10	BLDG 3	24

The difference between applying weights derived from the influence determined by PC to the original GOM scores was shown in Table 4 and Table 5. With the adjusted GOM scores, insights into each building's priorities on green practices highlighted areas in need for improvement. Building 1, Building 4, and Building 7 received consistently high scores even after adjustments, suggesting that they have well-rounded practices in key aspects such as Waste Management and Energy Efficiency. This stability in high scores implies that these buildings prioritize influential practices and reflect

effective GOM. In addition, buildings such as Building 2 and Building 6 saw slight increase which indicates good perform in most areas but also fall short on heavy-weighted categories resulting to lower impact on GOM scores. Building 5 retained the same total GOM score even after the adjustments, suggesting a balanced approach on both high-impact and lower-impact aspects. However, this leaves the mentioned building room for improvement in aligning practices with the most impactful areas like Management. Notably, Building 3, Building 8, and Building 9 experienced a significant decrease, suggesting a misalignment in their focus. These buildings likely invest in lower-impact areas, such as Transportation and Indoor Environmental Quality, rather than improvements on high-impact practices. Remarkably, Building 10 achieved a substantial increase in score and became the highest scorer for GOM despite its weaknesses in specific categories. This showed that high performance in critical areas lead to a higher total score even if certain areas receive less emphasis. Obtaining a low score on the aspect, Use of Land and Ecology, helped the building attain a higher GOM since this factor negatively contributes to the total score. Overall, the adjusted scoring implies that high-scoring buildings excel by prioritizing critical factors, while moderate and lower-performing buildings may need to reevaluate their focus and shift resources towards the aspects that are more influential to effective green operations management. Thus, buildings are encouraged to align their strategies and prioritize aspects with greater influence to promote a more objective and impactful approach to sustainability.

C. *Method of Green Operations Management*

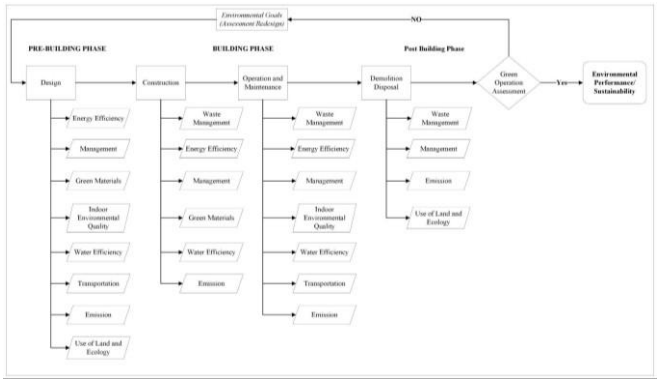


Fig. 10. Green Operations Management Model.

After analyzing the data using the Pearson Correlation Analysis and Multiple Regression Analysis pertaining to each green operations management (GOM) practice, a GOM model is then created. This model draws upon the life cycle of green buildings, depicted by Hassan Al-Ramadani (2022), as well as the construction and maintenance processes of green buildings illustrated by Xiang et al. (2022). Utilizing this sample model, the researchers were able to identify various construction phases and the corresponding GOM practices applicable to each phase. Through correlation and regression analysis, the researchers ranked these GOM practices according to their significance, based on data collected from ten buildings. The results indicated that waste management emerged as the highest priority, while use of land and ecology was deemed the least significant factor.

The proposed model employs simple shapes to aid building managers in analyzing their processes. Rectangles denote the various steps involved, showing the anticipated outcomes at each stage. Trapezoids represent the inputs and outputs related to these steps. When building managers effectively implement GOM practices, they can be assured that the tasks will align with GOM standards. Diamonds indicate the assessment of the building, representing the potential LEED certification or BERDE rating achievable through their GOM practices. A favorable assessment reflects strong environmental performance and sustainability, while an unfavorable assessment will necessitate further review and redesign. Arrows illustrate the progression of each step, and ellipses mark the conclusion of the model.

Moreover, instead of merely evaluating whether a building is considered green, the focus is on the building's goal of achieving sustainable status. This model promotes resource efficiency and sustainability in construction while reducing the adverse effects of building activities on both individuals and the environment. Even more so, to encourage construction to adopt green operation management, Al-Ramadani (2022) suggests that the practice of sustainable construction can also incorporate innovative solutions and technologies that facilitate the creation of greener and more efficient buildings.
Knowing that these practices are evaluated by the highest ratings of LEED and BERDE, it can be used as a good source of evidence that the factors on each phase must be supervised and always follow GOM practices.

IV. Conclusion And Recommendation

A. *Conclusion*

A construction project's main issue is the responsibility of minimizing its environmental impact while achieving quality production and operation requirements. Noise, air, water, and land pollution were perceived from construction sites in Metro Manila, particularly in Taguig City; air pollution, water pollution, noise, and light pollution are recorded to have a high index. With the rapid growth of pollution in the city, the application of Green Operations Management is an effective practice for production and operation in buildings to promote environmental safety, resource conservation, and sustainable development. Thus, this paper studied the efficacy of GOM in performing sustainable construction through identifying critical factors and formulating a systematic process to help in promoting resilience and sustainability and mitigating climate change.

The study observed 10 residential and commercial green buildings within Taguig City focusing on the 9 BERDE indicators and their environmental performance. Assessing these buildings, which may or may not intentionally practice GOM, was beneficial to the construction industry by recommending methods of GOM

that eventually result in limiting the detrimental effects of building construction on humans and the environment. It was identified in the study to have the GOM practiced in the building as the independent variable while the Environmental Performance achieving Sustainable Construction as the dependent variable. To achieve this paper's objectives, the study was broken down into four phases with the first phase identifying factors from relevant studies, second phase evaluating GOM practices among Taguig developers, third phase data analyzing using Multiple Regression and Correlation to assess GOM's impact on sustainability, and fourth phase developing a GOM model for sustainable construction.

The critical factors were identified in the Core Framework of BERDE Green Building Rating Schemes Version 3.0.0, published in 2019. The BERDE certification in the Philippines focused on 9 core frameworks for sustainable building, including Management, Use of Land and Ecology, Energy Efficiency and Conservation, Water Efficiency and Conservation, Waste Management, Green Materials, Transportation, Indoor Environment Quality, and Emissions. In comparison to both analyses, different sets of positive and negative relationships were discovered. Multiple Regression Analysis, which was the primary data on which the GOM model was based, observed a positive relationship with Environmental Performance on the aspects of Emissions, Energy Efficiency, Waste Management, and Indoor Environmental Quality and a negative relationship on Use of Land and Ecology, Management, Water Efficiency, Green Materials, and Transportation. On the other hand, Pearson Correlation Analysis documented a positive relationship with most of the aspects, excluding Use of Land and Ecology. Correlation Analysis was used to support the Multiple Regression Analysis because of the multicollinearity and overfitting that may occur, even though the latter analysis proved the significance of GOM's influence on improving the building's Environmental Performance.

There were still aspects of GOM practices that were inefficiently performed, resulting in harm to its environmental performance, such as the Use of Land and Ecology. Yet, there are aspects that were proven to have a great influence in increasing the building's environmental performance, such as Waste Management, Energy Efficiency, and Indoor Environmental Quality. The weighted GOM grading system explains the importance of prioritizing influential aspects for achieving sustainability. Buildings, like Building 10, excelled by focusing on these critical areas, while those with lower scores showed a need to shift resources toward more impactful practices. This approach encourages buildings to strategically target high-impact aspects to achieve more effective green operations management.

Therefore, the utilization of the Green Operation Management (GOM) model can be a tool to aid construction and building maintenance by observing its green operation management before, during, and after construction. Each of the following items underscores the building's dedication to environmental responsibility, adherence to regulatory standards, and assurance of quality. Furthermore, the model serves as a critical tool in evaluating the extent to which each product contributes to the attainment of Green Building Certification credits.

B. Recommendation

Researchers could consider expanding data collection methods by utilizing surveys, interviews, and case studies from multiple stakeholders, including local contractors, environmental consultants, and building occupants. In addition, it is suggestive for future studies to develop a better partnership with construction firms and building authorities to address data scarcity and collaboration barriers. Other than construction firms and building authorities, collaborating with regulatory bodies could facilitate easier access to data and incentivize green practices in construction. Applying such improvements involves gathering a bigger sample size than 10 observations, preferably in the range of 30-100 observations. More accessible data would allow researchers to analyze and confirm results more effectively. With a greater sample size, using more advanced tools for analysis such as Structural Equation Modeling and Life Cycle Assessment would support in proving the strength of relationships between variables and evaluate the environmental impact of management throughout the life cycle. If the acquired data is still limited, exploring more in-depth or qualitative research methods is more effective with smaller datasets, which could also help get clearer findings and provide results more applicable to similar projects across regions. To effectively gather and analyze data on environmental impact and construction practices, it is ideal to execute data gathering during the construction phase and post-completion phase, which takes years. Thus, a long-term study and consistent communication with construction projects are required to produce a more in-depth analysis of the effects of GOM on sustainable construction. Assessing construction methods and environmental performance using various Green Building Rating Systems such as WELL, BREEAM, DGNB, and BEAM PLUS would address different aspects of sustainability and facilitate comparisons across projects globally. Construction projects are encouraged to use the GOM Model to ensure that sustainable practices are performed effectively. Encouraging green practices through policies and building codes would also support more environmentally responsible construction in the long term.

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