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Green Solution Operation: Time, Cost, and Industry Perception in Implementing Green Solutions for Low-Cost Housing Projects in the Philippines

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Abstract—**The construction industry has a significant impact to rapid economic growth and development resulting to some serious ecological challenges. Hence, the use of green solutions has become increasingly utilized as a factor to sustainability. This study aims to provide a reasonable evaluation on the integration of green solutions to low-cost housing in the Philippines. This is undertaken to further improve the justification of using green construction methods with focus to time, cost, and overall project scheduling. This research uses a quantitative approach through online and face-to-face surveys focusing on green solutions' impact to schedule delays and accelerations; to various green building techniques such as energy efficiency, resource utilization and maintenance cost; and lastly, to planning and execution phases of the project. Using the RRLs, the researchers recognize the viewpoints perceived from conventional building techniques to green building techniques. Through presenting these comparisons and by offering practical recommendations, the study identifies the strategic planning perspectives for green solution adoption and contributes to achieving sustainability and affordability to the construction industry specifically in low-cost housing projects in the Philippines.**

Keywords—project scheduling and timelines, green building, green construction management, conventional building, low-cost housing.

I. INTRODUCTION

Housing is a basic necessity that ensures every individual's privacy, safety, and welfare. However, with the continuously growing population in the world, this basic need is not being acquired by many individuals. According to [1], this societal issue is caused by an array of economic, cultural, social, and societal factors. In 2021, the World Economic Forum reported that around 1.2 billion people do not have proper dwellings in the whole world. Meanwhile, in the Philippines, the Philippine Statistical Authority tallied over 4.5 million homeless Filipinos in 2018 [2] [3] [4].

To address the dilemma on housing, governments, in partnerships with developers all over the world, have initiated numerous mass housing initiatives that aim to cater millions of beneficiaries. While this is a good project for the people, the constant urbanization elevated in number has imposed an additional strain on the construction sector, primarily the economically disadvantaged housing market, which is in high demand but has limited availability. For this reason, the emergence of low-cost housing existed [5].

With expanding costs for housing since the beginning of the 21st century, the gap between poor and wealthy individuals has grown, emphasizing the necessity for affordable housing [6] [7] [8]. The situation is worsened by global economic issues, rendering housing affordability a top priority for researchers worldwide[2] [9] [10]. Low-cost housing consists of units built with cost-effective construction materials and efficient design, which are reasonable to those with earnings below the average household income [4] [11] [12] [13]. In several developing countries, affordability is heavily determined by individuals' financial resources, putting more pressure on governments to accommodate the growing demand for cheap housing. The goal of affordable housing is to minimize spending money without sacrificing the quality of materials [15] [16] [17] [18] [19]. It aims to reduce building costs by improving management and maximizing local assets, expertise, and technology while preserving the building's integrity and functionality. Low-cost housing can be established with the same foundational layout and strength as conventional houses but with more cost-effective procedures and materials. Strategic financial management, optimal use of locally accessible resources, and planned execution are all ways to cut costs without sacrificing quality [7] [20] [21] [22] [23].

While this movement slowly helps the world address the issue of housing, another challenge, on the other hand, arises - the deterioration of the environment. At the environmental scale, housing must foster waste minimization, material and energy efficiency, and lower greenhouse gas emissions, therefore incorporating green solutions into low-cost housing development is the answer of modern engineers [5] [24] [25]. With that being said, this study aims to assess the time and cost efficiency of adopting green solutions when constructing low-cost housing, as well as the view of civil engineers, project managers and other stakeholders and individuals who have experience in construction [26] [27] [28] [29] [30].

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II. MATERIALS AND METHODS

It is a sustainable construct discourse in which technology and human experience meet green building [31] [32]. Green construction management gives other conventional built systems limitations on how to make freshwater savings, water budget, and affordable housing. Studies emphasize using sustainable componentry and radical technologies (i.e., solar panels, low-emissivity windows, green roofs) counteracting opportunistic solutions with significant application-relevant environmental burdens to ensure positive emissions abatement concurrent economic prosperity via utility pricing/maintenance expenses reductions. Furthermore, the healing and wellness benefits also occur when biophilic approaches are used in green buildings, which favorably increases human mental health and productivity. These results emphasize the need to provide stronger regulations and other incentives, including tax breaks and reductions in permit fee support, for green building practices to be widely adopted. In addition, the green construction management (CM) section emphasizes up-to-date project implementation methods, such as scheduling techniques, by identifying leadership for sustainability initiatives to progress. It shows a direct link from using applications so that more projects are completed effectively within sustainable borders [33].

The former stand was criticized for using non-renewable and energy-hungry materials, such as cement or steel, to a large extent, which is very environmentally intrusive. Economic studies demonstrate that the energy consumption and maintenance practices of a conventional building ultimately result in much higher lifecycle costs despite relatively lower initial costs. This underscores the argument for green building practices - they cost more upfront but lead to savings and environmental benefits down the road. Finally, the report also discusses drawing from innovative construction techniques and robust policy support to sidestep some of the pitfalls associated with designing weather-resilient housing at an economy-wide level that remains affordable, high-quality, and sustainable. These findings offer a broad perspective of the integrative nature of sustainable principles concurrent with current construction and urban planning, driving home that sustainability as an approach is best approached comprehensively with symbiosis between environmental aims, economic craftiness, and social sustenance [34] [35].

III. RESULTS AND DISCUSSIONS

For Objective #1: Analyze the initial and long-term economic advantages and costs of adopting green building methods, focusing on a) Energy Efficiency, b) Resource Utilization, and Maintenance Cost.

Table 1. Energy Efficiency

Questions	Strongly agree (5)	Agree (4)	Neutral (3)	Disagree (2)	Strongly disagree (1)
The use of energy-efficient technologies (e.g., solar panels, efficient lighting) has led to noticeable long-term energy savings in my projects.	36	34	10	0	0
The initial cost of energy-efficient solutions is outweighed by the long-term savings.	39	33	8	0	0

Table 2. Resource Utilization

Questions	Strongly agree (5)	Agree (4)	Neutral (3)	Disagree (2)	Strongly disagree (1)
The use of recycled or sustainable materials lowers project costs and improves resource efficiency.	28	40	11	1	0
Green solutions have improved the effective use of resources (such as water and raw materials)..	34	39	7	0	0
Finding environmentally friendly building materials for affordable housing projects is simple.	38	28	11	3	0

Table 3. Maintenance Cost

Questions	Strongly agree (5)	Agree (4)	Neutral (3)	Disagree (2)	Strongly disagree (1)
Green buildings require less maintenance than traditional buildings.	31	31	17	1	0
The maintenance of green technologies (such as solar panels and water-saving systems) is more expensive compared to conventional ones.	31	34	17	2	0
Sustainable materials are required to be replaced less frequently.	31	38	10	1	0
Building performance has improved in general because of sustainable construction technologies, which also require less maintenance.	32	34	12	2	0

Hypothesis:

Null Hypothesis (H0): There is no significant difference in energy efficiency costs, maintenance cost, and resource utilization between green building methods and traditional building methods.

Alternative Hypothesis (H1): There’s a significant difference in energy efficiency costs, maintenance cost, and resource utilization between green building methods and traditional building methods.

Table 4. “Before” and “After” Monthly Bill Comparison

		Month 1	Month 2	Month 3	Average Monthly Bill		Percentage Reduction
Data 1	Before	6140.35	6816.42	6203.28	₱ 6386.68	14 panels	33.76%
	After	3413.03	4420.33	4857.241	₱ 4230.20	4kw	
	P-value	**0.035313055**					
Data 2	Before	17628.43	14726.96515	16493.84	₱ 16283.08	28 panels	69.13%
	After	4956.07	5026.059043	5102.36	₱ 5028.16	8 kw	
	P-value	**0.005794659**					
Data 3	Before	9620.06	9698.42	8730.16	₱ 9349.55	21 panels	47.11%
	After	6036.98	4640.64	4158.25	₱ 4945.29	6kw	
	P-value	**0.00956614**					

Table 4 shows that all the p-value are less than 0.05, therefore reject the null hypothesis. This indicates that there's a significant difference in energy efficiency costs, maintenance cost, and resource utilization between green building methods and traditional building methods.

In all the information from the data sets, the average monthly bills have significantly

decreased as a result of the adoption of green solutions. This clearly illustrates a financial benefit. The following cost savings have been observed:

For Data 1: The average monthly bill decreased by approximately 33.76%, dropping from ₱6,386.68 to ₱4,230.20.

For Data 2: The average monthly bill decreased by approximately 69.13%, dropping from ₱16,283.08 to ₱5,028.16.

For Data 3: The average monthly bill decreased by approximately 47.11%, dropping from ₱9,349.55 to ₱4,945.29.

This finding shows that green solutions, specifically using solar panels, can significantly reduce operational costs, with average monthly savings ranging from one-third to two-thirds of the original expenses. The cost efficiency shown here provides tangible data or support for adopting green solutions in low-cost housing projects, which underscores the potential for longterm financial sustainability.

Table 5. Savings and Payback Period

	Monthly Savings	1 year	5 years	10 years	Installation Cost	PaybacK period
Data 1	₱ 2156.483	₱ 25,877.80	₱ 129,388.98	₱ 258,777.96	₱ 348000	13+ years
Data 2	₱ 11254.915	₱ 135,058.98	₱ 675,294.92	₱ 1,350,590	₱ 658000	4+ years
Data 3	₱ 4404.2567	₱ 52,851.08	₱ 264,255.40	₱ 528,510.80	₱ 450000	8+ years

The table shows the Savings and Payback Period. It can be concluded that adopting green building techniques leads to improved energy efficiency, resulting in long-term cost savings for homeowners or building managers. However, in terms of paying back the initial cost, it may take more than 4 years to pay back the installation cost. This concludes that investment in green building technologies, such as solar panels or energy-efficient appliances, provides significant long-term savings on energy costs, but the initial outlay can take some time to recover.

For Objective #2: *Determine how civil engineers perceive the application and relevance of green building practices mainly geared toward low-cost housing.*

The researchers assigned the respondents into two groups. The data consists of responses from two groups: 0–10 years and 11+ years of experience and each respondent has provided scores for several questions (Q9–Q17). This involved comparing the perceptions between civil engineers' different years of experience. Chi-square test is used since the data is categorical and they are examining the relationship between two categorical variables (010 years vs. 11+ years). In this case, the researchers could test whether experience level is significantly associated with a particular survey response.

Table 6. Respondents' Perception

Questions	Strongly agree (5)	Agree (4)	Neutral (3)	Disagree (2)	Strongly disagree (1)
I am knowledgeable about the latest green building technologies and methods.	33	33	12	2	0
I am aware that implementing green building practices in low-cost housing projects has positive impacts on the environment.	32	36	8	4	0
The benefits of green building solutions are sufficiently known in the construction industry.	29	36	13	2	0
Green building techniques are very important for the Philippines' future low-cost housing.	31	37	9	3	0
Green building solutions are generally affordable for low-cost housing projects.	29	33	16	2	0
In general, clients are in favor of green technologies being incorporated into low-cost housing projects.	29	34	15	2	0
The main barrier to the implementation of green solutions in affordable housing is their high initial cost.	30	37	10	3	0
The high initial cost of green solutions is the main barrier	33	34	10	3	0

to their adoption in low-cost housing.					
The large-scale implementation of green solutions in low-cost housing is possible.	30	36	11	3	0

Hypothesis:

Null Hypothesis (H_0): Civil engineers' perceptions of the relevance and application of green building practices in low-cost housing do not vary significantly based on years of experience.

Alternative Hypothesis (H_1): Civil engineers' perceptions of the relevance and application of green building practices in low-cost housing vary significantly based on years of experience.

** 0.05, meaning 5% risk of rejecting the null hypothesis when it is actually true*

Table 7. Chi-squared Test Criteria

If the p-value < 0.05	There is a significant difference between the two groups' responses.
If the p-value > 0.05	The difference is not statistically significant.

** 0.05, meaning 5% risk of rejecting the null hypothesis when it is actually true*

Table 8. Chi-square Test

Q9	0.610818929
Q10	0.352232321
Q11	0.801970386
Q12	0.572731091
Q13	0.479825321
Q14	0.662042803
Q15	0.261968913
Q16	0.720637643
Q17	0.824804604

In this study, the researchers examined civil engineers' perspectives about the relevance and application of green building practices in low-cost housing especially considering their years of experience. Table 12 shows p-value larger than 0.05 was found by the statistical analysis, suggesting that there is no statistically significant difference in the perceptions of civil engineers with different levels of experience.

As a result, the researchers agree with the null hypothesis, which states that the years of experience of civil engineers have no significant impact on their views about the relevance and application of green building practices in low-cost housing.

The finding of no significant difference suggests that civil engineers have similar views and perspectives regarding green building practices in affordable housing, irrespective of their years of experience. This may suggest that people with different levels of experience understand and accept the concept of green building and how to apply it. It might also imply that green practice education and training successfully address these ideas, promoting a shared knowledge among civil engineers at various career stages. Furthermore, it's possible that the value of green building techniques is seen as being universal, as all civil engineers, regardless of experience level, view these practices as significant toward low-cost housing.

For Objective 3: *Assess the strategic planning perspectives for green solution adoption, focusing on the quantifiable impacts on time and cost.*

This data set was subjected to a t-test, because it is an appropriate approach for comparing the means of two independent groups and figuring out whether the differences between them are statistically significant.

Table 9. Strategic Planning Perspectives

Questions	Strongly agree (5)	Agree (4)	Neutral (3)	Disagree (2)	Strongly disagree (1)
Careful strategic planning helps mitigate the higher initial costs of green solutions.	29	44	6	1	0
Incorporating green solutions into the project plan is challenging due to a lack of expertise or experience.	33	36	10	1	0
I regularly consider long-term cost savings (e.g., energy and maintenance) when planning green solutions in housing projects.	36	35	8	1	0
The decision to implement green solutions is usually influenced by the availability of local resources and materials.	36	36	7	1	0
Green building methods generally extend the timeline for project completion.	30	37	10	3	0
Green solutions in low-cost housing projects often exceed the initial project budget.	36	35	5	4	0
Incorporating green solutions in the early design phase reduces overall project costs.	31	39	9	1	0
Adopting green solutions early in the planning phase	35	37	6	2	0

reduces the overall impact on project timelines.					
Green solutions lead to faster project completion in the long term due to lower maintenance and operational needs.	40	29	10	1	0

Hypothesis:

Null Hypothesis (H_0): The strategic planning perspectives for green solution adoption, in terms of time and cost, do not vary significantly between the different professional groups (Civil Engineers/ Architects/Other Engineers and “Others”). **“Others” includes Project Managers, Quantity Surveyor, etc.*

Alternative Hypothesis (H_1): The strategic planning perspectives for green solution adoption, in terms of time and cost, vary significantly between the different professional groups (Civil Engineers/ Architects/Other Engineers and “Others”).

Table 10. Average Scores from the surveyed data

	Civil Engineers, Architects, Other Engineers	Others
Q1	4.339285714	4.083333
Q2	4.357142857	4.041667
Q3	4.339285714	4.291667
Q4	4.375	4.25
Q5	4.178571429	4.166667
Q6	4.339285714	4.166667
Q7	4.25	4.25
Q8	4.321428571	4.291667
Q9	4.446428571	4.125
p-value	0.002395	

A p-value less than 0.05 was found by the analysis, suggesting that the two groups' differences are statistically significant. The findings indicate that when it comes to the adoption of green solutions, the perceptions or ratings of Civil engineers, architects & other engineers are very different from those of “Others”. More specifically, these variations might be a reflection of different views about how green solutions affect project budgets and schedules. Professionals with technical backgrounds, like civil engineers and architects, might perceive the long-term cost and efficiency benefits of green solutions more favorably than others, while people in the "Others" category might consider adopting green practices to be more difficult or expensive in the short run.

This finding highlight how important professional experience and technical expertise are in influencing perceptions of green solutions and emphasizes the possible impact of professional background and technical expertise regarding sustainable building practices. These variations highlight how important it is to customize communication and strategic planning methods when promoting green solutions, in order to properly address the various perspectives of different stakeholder groups are addressed effectively.

This conclusion directly addresses Objective 3, which focuses on Strategic Planning and Adoption of Green Solutions, specifically examining the influence of professional background and expertise on the effectiveness of implementing green solutions in housing projects. The variation in perspectives indicates that green solutions' strategic adoption must be flexible, with planning processes that accommodate different professional inputs. Thus, making sure that these inputs are taken into account in the early planning and design phases will improve collaboration, in which will improve smoother implementation and decisionmaking.

CONCLUSION

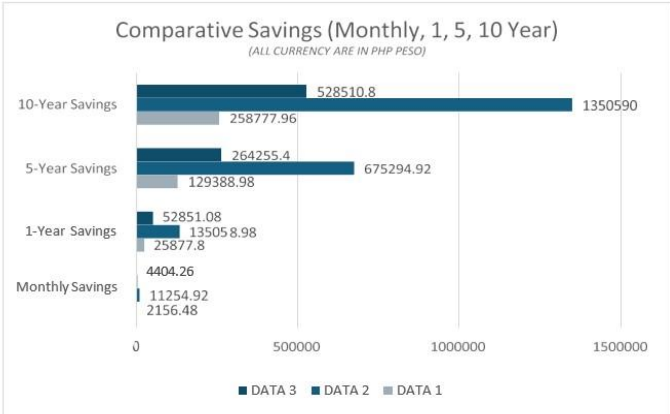

Fig. 1. Comparative Savings (Monthly, 1, 5, 10 Year)

To conclude, households with a longer-term focus or are not initially financially constrained can benefit from Data 1 since it offers ₱258,777 savings after 10 years. In contrast, the most cost-effective option is Data Set 2, which offers immediate and substantial long-term and monthly savings. It provides the best financial return, particularly for households trying to maximize energy savings and lower utility bills, with monthly savings of over ₱11,000. On the other hand, Data Set 3 provides a balanced option, offering moderate monthly savings but delivering significant long- term benefits of ₱528,510 after 10 years.

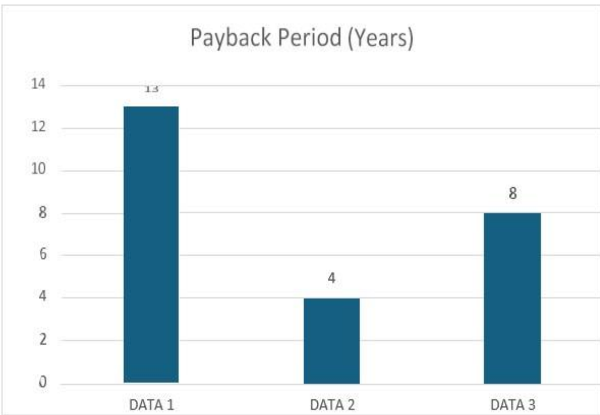

Fig. 2. Payback Period (Years)

Each of the data set's payback periods shows the duration it takes for households to save enough money to cover the initial investment made in green solutions. Data Set 1, with a payback period of more than 13 years, takes the longest to recover the initial investment, which makes it less appealing for households looking for a faster return.

For households looking for a quick return on investment, Data Set 2 is the most cost- effective choice because it has the shortest payback period, at about four (4) years. For households with a long-term financial outlook, Data Set 3's moderate payback period of eight years is still relatively attractive.

Data Set 1 has the longest payback period which is more suitable for households looking to make long-term investments. This makes it less ideal for households needing faster return but still reasonable for those who are concerned with sustainability over the long run.

Data Set 2 has the most-cost-effective choice for households aiming for faster financial return. Households can begin to see the benefits of green solution relatively soon with a payback period of approximately four (4) years.

Data Set 3 has a moderate payback period of eight (8) years making households with a longer investment horizon may find it appealing. The savings overtime validate the longer wait especially for households who can tolerate a little longer payback period.

Assumptions about key variables like energy, installation, and maintenance costs can significantly affect financial or cost analysis results. Understanding how changes in these variables could influence savings and payback periods is essential.

The savings and payback period may change if the energy cost decreases

or increases. Therefore, savings are highly dependent on energy costs.

The payback period would be extended if the installation costs decreased or increased; therefore, installation costs are an important factor in determining the payback period.

Maintenance costs may vary depending on the green solution implemented.

However, if maintenance costs increase, it can reduce the overall savings.

Households can adjust decisions based on forthcoming uncertainties. By considering these factors, households can make better decisions that support their short—and long-term financial objectives.

This research indicates that civil engineers, irrespective of their professional backgrounds, tend to share similar opinions regarding the application and relevance of green building techniques in the context of low-cost housing. The successful implementation of green solutions requires sensible planning to balance the time and cost limitations. The professional's perception plays an important role in whether green solutions can be implemented in low-cost housing. However, there are still limited studies locally, and green building practices in the Philippines are slowly expanding.

In summary, the analysis concludes the following: (1) Although implementing green building techniques may result in a delayed payback period, the long-term cost savings and ecological advantages make it a beneficial spending for individuals seeking to improve their buildings' energy efficiency and sustainability, (2) The years of experience of civil engineers has no significant impact on their views about the relevance and application of green building practices in low-cost housing, and civil engineers with different levels of experience understand and accept the concept of green building and how to apply it, and that the value of green building techniques is seen as being universal, as all civil engineers, regardless of experience level, view these practices as significant toward low-cost housing, (3) Project managers and planners can develop more successful strategies that take into account different points of view by acknowledging these differences, which will ultimately result in the adoption of sustainable building practices being carried out more successfully and efficiently. By addressing time and cost concerns early in the planning process, this improves project outcomes and guarantees that green solutions are adopted in a way that is both workable and well-supported throughout the team.

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