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# ANALYSING INNOVATION AND SUSTANABILITY IN CONSTRUCTION: THE CASE OF PLASTIC BOTTLE HOUSES IN THE YOPIPILA PROJECT IN CABO DELGADO, MOZAMBIQUE

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***ABSTRACT*:**

The Yopipila Project initiative implemented in Cabo Delgado, Mozambique, proposes an innovative solution for the construction of houses using recycled plastic bottles. This research analyzes the creativity and sustainability aspects of the initiative, evaluating its effectiveness through four main dimensions: structural resistance, economic viability, environmental impact and operational challenges. The methodology used to carry out the study combined technical analysis with qualitative data, which were obtained through questionnaires and interviews submitted to residents as well as technicians responsible for the construction of houses made of plastic bottles. The results obtained demonstrate that the project: recycled nearly 31,000 plastic bottles, reduced construction costs by 40%, compared to traditional methods used for building houses in the region, produced buildings with good structural resistance, as well as being able to offer excellent thermal and acoustic insulation. Despite the benefits, significant challenges were identified, including: total financial dependence on external sources for the construction of the houses, and the need for complex logistics for the acquisition and preparation of the necessary materials. The data obtained in the study confirm that the use of recycled plastic bottles represents a viable and sustainable alternative for construction in contexts with limited resources, combining economic and environmental benefits. The study concludes with recommendations for improving operational efficiency, financial sustainability and viability.

***Keywords**: Cost-Effectiveness, Innovative Construction, Plastic Bottle Houses, Recycled Materials and Sustainability.*

## 1. INTRODUCTION

Today, there has been a fervent search for more efficient and cheaper methods that meet housing needs, that has a good cost-benefit ratio and, last but not least, that guarantee longevity in the construction processes. With these aspects in mind, the initiative of the Yopipila project, which was developed in the province of Cabo Delgado in Mozambique, emerges as a milestone in sustainable architecture by using recycled plastic bottles as the main structural component of residential housing.

Located in the extreme north of Mozambique, Cabo Delgado is among the most deprived regions of the country, facing a shortage of affordable construction materials, financial fragility and environmental degradation. The traditional methods of the region that have been conveniently employed in recent years use clay bricks and grass roofs, and these have already proven to be very short-lived and ecologically problematic due to their fragility. Yopipila proposes a transformative solution by reusing plastic waste as the main raw material, in order to provide a broader and more up-to-date vision of alternative construction methods, thus reducing the shortage of resources for this purpose.

One of the most relevant and/or revolutionary aspects of this project is its dual approach, which as: technological advancement combined with ecological practices. The study carries out a critical analysis of the merits and limitations of the proposal, evaluating its overall effectiveness and potential as a reference for buildings in similar contexts; and by examining the implementation strategies and possible obstacles overcome, the research carried


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out offers a broad understanding of how creative solutions can reformulate the construction segment, in order to enhance environmental resilience, financial viability as well as operational efficiency.

In addition, this work aims to elucidate the pros and cons of using recycled materials in construction, investigating the possibility of replicating these methods in areas that face similar challenges or the same type of scarcity. Finally, the research aims to broaden the academic debate around sustainable architecture, presenting initiatives such as Yopipila as catalysts for a greener and more resilient future. The figure 01 shows the construction process.

***Figure 01: Plastic Bottle Houses-Yopipila Project, Cabo Delgado – Mozambique***
***Source: Yopipila Project Archive (2024)***

## 2. METHODOLOGY

The study combined two methods (qualitative and quantitative) to analyze the environmental, economic and social impacts of this construction method approach to assess the sustainability and innovation of constructions using plastic bottles in the Yopipila Project.

In the first phase (qualitative), semi-structured interviews were conducted with those involved in the project, that is, it included local residents, Engineers and Managers responsible for building the houses, with the primary objective of capturing perceptions about the practical advantages and challenges of using this type of construction. Following this, direct observation of the buildings was conducted to record functional aspects and everyday use; where the data collected was subjected to more in-depth thematic analysis, categorizing the information and subdividing it into categories such as: innovation, social acceptance and ecological impact.

The 2nd phase (the quantitative dimension) focused on objective metrics such as cost reduction compared to traditional methods, volume of plastic waste reused and durability of structures; where descriptive statistics were used to process the data, generating comparative indicators.

The method used was based on a detailed case study, validated by multiple sources. The intentional sample included 39 participants, including residents, construction professionals and administrators, in addition to a subset of seven residents for initial representation, due to the lack of consolidated demographic data. The research also included the review of project documents and specialized literature on sustainable buildings.

The research was conducted with three (03) main objectives in mind:

1. To describe the construction system, analyzing materials, techniques and structural efficiency;
2. To compare the economic and environmental performance in relation to conventional methods used for construction; and


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3. To formulate recommendations for application in similar contexts, considering cultural, technological and financial variables.

Among the limitations identified in the context of conducting the study, difficulties in accessing detailed documents and restrictions in the fieldwork were noted. All participants provided informed consent, with guarantees of anonymity and confidentiality of the data provided, in accordance with ethical research principles. The methodology employed allowed for a balance of concrete evidence and contextualized perceptions, ensuring a comprehensive evaluation of the initiative.

## 3. PRESENTATION OF DATA

This chapter brings together the main findings on the plastic bottle houses implemented in the Yopipila Project in Cabo Delgado. The study collected data on a sample of 39 people involved in the survey, from residents to technicians and local leaders, to understand the different aspects of this method.

The construction technique used has shown several advantages. The bottles filled with sand or soil not only solve the problem of plastic waste, but also create walls that are so resistant that they keep the houses cooler and quieter. Compared to the normal constructions that are normally built in the region, the cost has fallen by 40%, which has been a relief for many families with low incomes. In addition to being affordable, the structures have proven to be resistant even in difficult weather conditions (Martinez & Pereira, 2021)

It was observed that the construction process culminated in a community activity; where the residents themselves helped to collect, clean and prepare the bottles. They were then filled and stacked with a special mixture, used to create solid walls. At first, many residents were skeptical about the method because it was something new and never seen before, but the practical results convinced the skeptics after seeing the great results.

Along the way, some partnerships were essential to overcome several of the obstacles observed. The training provided taught the technique, the donations of complementary materials received helped in the most difficult cases, and in the end, the teamwork resulting from the union of everyone solved the logistical issues that were observed. Today, in addition to cheaper houses, the project left as a legacy a new way of thinking about sustainable, creative and adapted to the local poor reality. Figure 02 illustrates a large part of those involved in the construction.

***Figure 02 and 03: Placement of plastic bottles to form the structural walls during the construction process. Source: Yopipila Project Archive (2024)***

The figures and testimonies show that the initiative was successful not only on paper, but also gradually improved the lives of those who gained a home, cleaned the surrounding environment and also served as an example for other communities to address their housing problems in an innovative and very creative way.


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## 4. RESULTS

This chapter presents the studies carried out on the Yopipila Project, which investigated the use of plastic bottles filled with sand as an alternative construction material in Cabo Delgado. The data analysis includes compression tests performed on plastic bottles filled with wet sand, the construction of prototype walls and a cost comparison between traditional constructions and those made with plastic bottles being implemented in Yopipila.

### 4.1. Prototype Walls and Compression Tests

Compression tests were carried out on plastic bottles filled with wet sand over 3 weeks, and the average compressive strength after 28 days was 2.0 MPa; and this value is lower than that of conventional concrete blocks, more equivalent to that of soil-cement blocks. According to Costa (2022), the bottles demonstrated reasonably adequate resistance, with the advantage of not requiring a curing process. Table 01 illustrates the results of the compression test carried out over 28 days.

***Table 01: Summary of the 4 Compression Test Tables***

| Age (days) | Average Weight (kg) | Average Force (kN) | Average Strength (MPa) |
|---|---|---|---|
| **1** | 3.18 | 48.4 | 2.1 |
| **3** | 3.28 | 46.6 | 2.0 |
| **7** | 3.15 | 44.2 | 1.9 |
| **28** | 3.20 | 46.83 | 2.0 |

The production of houses with plastic bottles generated significant savings: 90.57% in material costs; 40% in labor and 84.13% in transportation, resulting in a total savings of 89.26% per residence and a return on investment of 89.26%. In addition, the method proved to be ecologically advantageous and viable in extreme climate conditions, since:

a) Over time, the compressive strength of plastic bottles stabilizes, making them economically and environmentally beneficial for use in non-structural constructions;

b) The viability of the method was proven by the construction of a prototype wall with 26 plastic bottles (fig. 04), demonstrating that this technique is economically advantageous, sustainable and environmentally beneficial for non-structural walls.

***Figure 04: Prototype of a wall made of plastic bottles filled with wet soil***
***Source: By Author (2024)***

### 4.2. Implementation Cost Assessment

The study compared the construction costs between conventional houses and those made of plastic bottles, revealing significant differences, as illustrated in Table 02:


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*Table 02: Cost Comparison*

| Element | Conventional House (USD) | Plastic Bottle House (USD) | Difference (%) |
|---|---|---|---|
| **Construction Material** | 95,976.32 | 9,051.57 | - 90.57% |
| **Labor** | 2,500.00 | 1500.00 | - 40.00% |
| **Transport/Logistics** | 600 | 95.24 | - 84.13% |
| **Construction Time** | 90 days | 40 days | - 55.56% |
| **Total Cost** | 99,076.32 | 10,646.81 | - 89.25%. |

From the comparative analysis of costs for conventional houses compared to houses built from plastic bottles, it was found that:

a) Regarding materials, there was a 90.57% saving in material costs;
b) Regarding labor: there was a 40% reduction due to the need for less specialized labor;
c) Regarding transportation, there was an 84.13% reduction in transportation costs due to the use of local materials;
d) The time required for construction: houses made from plastic bottles take on average only 40 days to be built, compared to the 90 days required for houses built using traditional/conventional construction - a reduction of 55.56%; and finally, about the
e) Total cost: construction with plastic bottles costs 89.25% less than the conventional method

**4.3 Structural Comparison of Materials Used**

While traditional/conventional houses use concrete blocks, wood, and clay bricks, houses made of plastic bottles, filled with sand or compacted earth, are denser and more resistant, in addition to using the same finishing materials used in conventional constructions.

Looking at structural resistance, houses made of plastic bottles demonstrated:

a) Better resistance to deformations and impacts;
b) Excellent performance under severe weather conditions, such as heavy rains and strong winds.

During “Cyclone Chido” in the Cabo Delgado region, which occurred in December 2024:

a) Traditional houses (made of concrete blocks and zinc tiles) were severely damaged; however
b) Plastic bottle houses remained intact, thanks to their elasticity and ability to absorb and dissipate dynamic loads caused by cyclonic winds (this only intensified how resistant these structures are).

**4.4 Environmental Aspects**

The environmental aspects that were analyzed gave us the conclusion that:

a) Regarding the Ecological Impact: traditional construction contributes to deforestation and soil erosion; while plastic bottle houses reduce plastic waste, being ecologically sustainable.
b) Regarding Energy Efficiency: plastic bottle houses maintain more stable internal temperatures, reducing the need for ventilation or additional heating, that is, due to their density.

**4.5 Analysis of Technical and Economic Feasibility**

**4.5.1 Technical Feasibility:**

The project demonstrated that construction with plastic bottles is technically feasible, as evidenced by the tests and results presented in table 03:

*Table 03: Analyzed Technical Aspects*

| Aspect | Description |
|---|---|
| Available Materials | Plastic bottles are widely available in Cabo Delgado due to the high production of plastic waste. Their reuse promotes a circular economy and reduces environmental pollution. |
| Construction Process | Filling bottles with sand or inert materials, combined with conventional masonry techniques, requires only minor adaptations to traditional methods. |


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| | |
|---|---|
| Durability | Plastic bottles provide adequate structural resistance for small homes, as well as good thermal and acoustic insulation. |
| Environmental Sustainability | Reduces environmental impact by decreasing the use of materials such as cement and bricks, while also minimizing plastic waste in the environment. |

**4.5.2. Economic Viability:**

The economic viability is proven by the significant savings obtained with the use of plastic bottles in construction:

a) Material Costs: Savings of 90.57%, totaling USD 86,924.75;
b) Labor Costs: Reduction of 40%, equivalent to USD 1,000.00;
c) Transportation/Logistics Costs: Savings of 84.13%, totaling USD 504.76;
d) Total Construction Cost: Reduction of 89.26%, representing USD 88,429.51;
e) Construction Time: Reduction of 55.56%, falling from 90 to 40 days, ensuring faster deliveries.

**4.5.3. Visual Comparison and Observed Benefits:**

a) Sustainability and Durability: Plastic bottle houses are more resistant and durable than traditional clay and straw constructions;
b) Environmental Impact: They promote a circular economy by transforming plastic waste into raw materials for construction;
c) Social Inclusion: The low cost makes housing more accessible, and the method can be replicated in other contexts with similar challenges.

**4.6. Survey Results**

**4.6.1. Participant Contributions:**

a) Social Acceptance: The beneficiaries (local residents), initially resistant, began to value the structural resistance and thermal insulation provided by their new homes;
b) Technical Challenges: The locally generated solutions overcame obstacles such as the shortage of cement and the logistics of collecting plastic bottles for use in future buildings;
c) Economic Viability: The project under implementation proved to be financially sustainable in areas with limited resources, combining affordable housing and reducing plastic pollution in the region.

**4.6.2. Relevant Testimonials:**

a) Beneficiaries (residents) highlighted the advantages of thermal insulation and durability;
b) The technicians who participated in the construction recognized the initial difficulty in handling the material, but approved the final results

In figure 05, the result of one of the houses built with plastic bottles by the Yopipila project can be seen.

***Figure 05: Final state of one of the plastic bottles houses***
***Source: Yopipila Project Archive (2024)***


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## 5. CONCLUSION

The research on the use of recycled plastic bottles in the construction of residential housing has shown that this innovation is viable and promising. The method of filling bottles with sand and covering them with adapted masonry techniques has proven to be practical and efficient, making use of local materials and reducing dependence on conventional inputs. Economically, the results have been impressive: an 89.26% reduction in total implementation costs has been observed, making construction much more affordable. Environmentally, the technique helps to reduce plastic waste, promoting a circular economy and reducing environmental pollution in the region and surrounding areas.

The houses built using this method have demonstrated excellent performance: good thermal and acoustic insulation, as well as proven resistance during “Cyclone Chido” (which coincidentally occurred during the preparation of this study); when the houses in the project remained intact while traditional buildings were reasonably damaged by the phenomenon that occurred. This proves its potential to offer safe housing in risk areas. It was also observed that the project faced challenges such as the logistics of collecting and cleaning bottles and the initial resistance of the communities, which was overcome with awareness campaigns that were carried out with the aim of changing the way this issue was viewed.

Experience has shown that the model can be replicated in other regions, as long as it is adapted to local conditions. Surveys with residents, technicians and engineers revealed general satisfaction with the results, although suggestions were made such as more training to improve the quality of construction. In short, Yopipila has proven that building with plastic bottles is an innovative solution that combines sustainability, low cost and social benefits, paving the way for more resilient and affordable housing.

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## 8. DECLARATION OF CONFLICT

I hereby state that there is no conflict of interest in undertaking this study. All the information were collected ethically and objectively, free from institutions, companies or individuals who might compromise the integrity of the findings obtained.


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**REFERENCES**

1. Almeida, J. & Costa, M. (2022). Innovations in smart building technologies for energy efficiency. Energy Efficiency Review, 14(1), 85-100.
2. Almeida, J. (2021). The impact of recycled materials in construction. Journal of Sustainable Building, 12(3), 213-225.
3. Almeida, J., & Pereira, T. (2022). Circular Economy and Sustainability in Construction: Using Recycled Plastics as Materials. Journal of Green Engineering, 45(3), 241-263.
4. Costa, M. & Gonzalez, R. (2022). Economic implications of using recycled steel in construction. Construction Economics Journal, 29(2), 114-129.
5. Gonzalez, A. & Silva, L. (2022). Innovations in sustainable building materials. Sustainable Construction Journal, 19(2), 145-160.
6. Gonzalez, L., Costa, M., & Silva, R. (2021). Plastic Waste Solutions in Construction. Sustainable Building Technologies, 32(2), 112-131.
7. Martinez, P., & Oliveira, F. (2022). Recycled Plastic Bottles in Construction: Techniques and Case Studies. International Journal of Construction Materials, 18(1), 78-97.
8. Martinez, T. & Pereira, L. (2021). The role of BIM in improving construction efficiency. Journal of Construction Management, 18(4), 256-270.
9. Nhamo, G., Sibanda, M., & Mjimba, V. (2021). New construction methodologies for affordable housing in developing countries. Sustainable Construction Review, 12(3), 104-115.
10. Pereira, A., & Santos, J. (2023). Innovations in Green Building: Recycled Plastics as Structural Elements. Journal of Environmental Engineering, 60(4), 205-225.
11. Pereira, T. (2021). Challenges and solutions in the adoption of recycled materials in construction. Building Materials Journal, 18(4), 304-317.
12. Santos, D., & Silva, P. (2022). Plastic Bottles as Eco-friendly Building Materials. Waste Management and Construction Practices, 27(1), 89-104.
13. Silva, L. & Almeida, J. (2022). Advances in modular construction techniques.
14. Silva, L. & Martinez, S. (2021). Plastic bottle houses: Addressing housing and environmental issues in Mozambique. Journal of Environmental Design, 9(1), 45-60.
15. Singh, A., & Kumar, R. (2022). Earthbag and low-tech building practices: Solutions for sustainable and affordable housing. International Journal of Sustainable Building, 15(2), 213-229.
16. UN-Habitat. (2020). World Cities Report 2020: The Value of Sustainable Urbanization. United Nations.".


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