Zbornik radova Fakulteta tehničkih nauka, Novi Sad

UDK: 72.012
DOI: https://doi.org/10.24867/31FA21Abudajaja

POBOLJŠANJE URBANE INFRASTRUKTURE KROZ GENERATIVNI DIZAJN: PROTOTIP PAVILJONA U PREDGRAĐU NUAKŠOTA, MAURITANIJA

ENHANCING URBAN INFRASTRUCTURE THROUGH GENERATIVE DESIGN: A PAVILION PROTOTYPE IN NOUAKCHOTT'S SUBURBS, MAURITANIA

Muftah s.Abudajaja, Marko Jovanović, *Faculty of Technical Sciences, Novi Sad*

Oblast – ARHITEKTURA I URBANIZAM

Kratak sadržaj – *Ova studija istražuje korišćenje generativnog dizajna za poboljšanje urbane infrastrukture kroz održivi paviljon u Nuakšotu, Mauritanija. Koristeći Rhino i Grasshopper, dizajnira se modularni paviljon od recikliranih guma, koji rešava ekološke i socio-ekonomske izazove. Uključivanje zajednice pomaže u stvaranju prilagodljivih prostora. Analiza pomoću Kangaroo potvrđuje izvodljivost upotrebe recikliranih materijala, optimizujući izgradnju za izdržljivost i minimalni otpad. Paviljon predstavlja fleksibilan model koji kombinuje modernu arhitekturu sa održivim, zajedničkim rešenjima za poboljšanje urbane infrastrukture.*

Ključne reči: *paviljon, socijalno-ekonomski aspekti, dostupnost materijala, gume, dinamička simulacija*

Abstract – *This study examines generative design to improve urban infrastructure via a sustainable pavilion in Nouakchott, Mauritania. Using Rhino and Grasshopper, the project designs a modular pavilion from recycled tires, addressing environmental and socio-economic challenges. Community involvement aids in creating adaptable spaces. Kangaroo analysis confirms the feasibility of recycled materials, optimizing construction for durability and minimal waste. The pavilion presents a flexible model combining modern architecture with sustainable, community-driven solutions.*

Keywords: *pavilion, socio-economic aspects, availability of materials, tires, dynamic simulation*

1. INTRODUCTION

Pavilions have long been platforms for architectural innovation, allowing experimentation with materials and techniques. Early examples like the Crystal Palace and Barcelona Pavilion pushed design boundaries and conveyed societal messages. In modern architecture, digital tools enable more complex and efficient structures, as seen in the Underwood Pavilion, which uses the Tensegrity system for flexible, lightweight design. Pavilions now serve as architectural expressions of social, cultural, and environmental ideas [1].

Research Subject: This research examines how pavilions can address challenges related to rapid urban growth, inadequate infrastructure, and environmental concerns. Key questions include involving the local community in construction, simplifying the building process, selecting suitable materials, and the pavilion's contribution to environmental solutions. The research also explores how the pavilion can accommodate community activities, reduce construction costs, and integrate with the urban environment. Using parametric design tools, the study seeks to optimize material use and improve construction efficiency, offering new possibilities for pavilion design.

Research Objective: The research aims to explore the possibility of building a sustainable, multi-functional pavilion to address urban and environmental challenges. Key objectives include:

Innovation in Materials and Sustainability: Investigate the feasibility of using recycled tires as a primary building material, focusing on their structural and thermal properties to promote waste reduction and sustainability.

Simplicity in Construction: Design a pavilion that can be easily assembled by local communities using modular systems and basic tools, empowering locals with limited resources.

Structural Stability and Environmental Resilience: Ensure the pavilion can withstand harsh environmental conditions like high temperatures and sandstorms by optimizing tire arrangement through parametric design.

Multifunctionality and Community Needs: Create a flexible space that serves various community functions, such as social gatherings and markets, while adapting to local socio-economic contexts.

2. SITE ANALYSIS

Nouakchott, with a population of over 1.1 million people as of 2020, has experienced rapid urban growth since its founding in 1958 (Figure 1). Originally designed for around 15,000 residents, the city now faces sprawling informal settlements and inadequate infrastructure. Environmental challenges such as desertification, coastal erosion, and poor waste management have worsened due to this rapid expansion. Nearly 40% of Nouakchott's population lives in poverty, with many residents engaged in low-income jobs within the informal economy.

NAPOMENA:
This work originated from a master's thesis supervised by assistant professor Marko Jovanović

However, there are opportunities for sustainable development through initiatives like AREDDUN and modern architectural practices such as parametric design. This research seeks to use digital tools and sustainable methods to create multi-functional spaces that improve living conditions and serve as a model for similar cities [2].

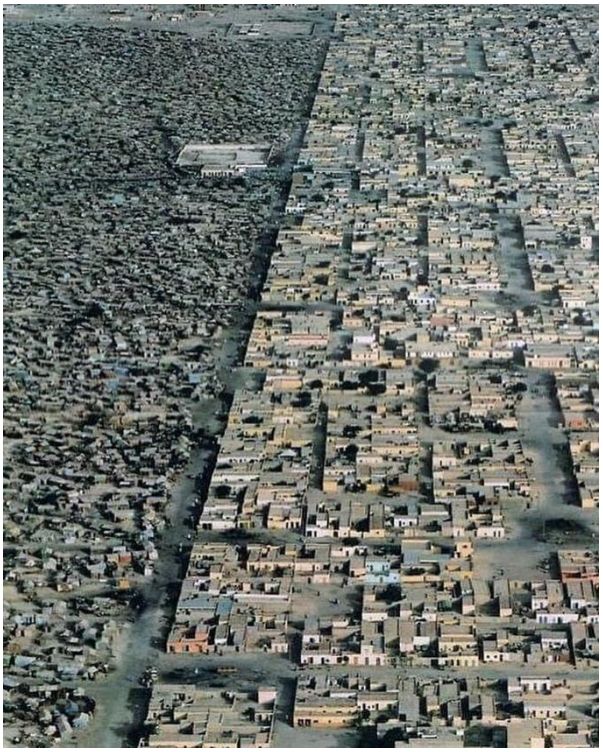

Figure 1 : *Aerial view of neighborhoods in Nouakchott, showing the contrast between planned and unplanned areas* [3]

3. METHODS

Material Testing : Tires possess several key properties that make them suitable for sustainable construction. They exhibit high tensile strength (10-25 MPa), allowing them to resist stretching forces, while their compressive strength (11-22 MPa) is lower, but they help improve flexibility and shock absorption. Tires are durable, impact-resistant, and have good elasticity, making them ideal for absorbing shocks. Additionally, they offer thermal insulation, helping to mitigate heat transfer in urban settings. By recycling tires for construction, this project aims to reduce waste and leverage their strength, durability, and environmental benefits, making them an attractive material for sustainable architecture in Nouakchott. Further testing will ensure their effective use in local construction.

Tires Grid: The Tire Grid System creates a fabric-like network of tires arranged in a repeating hexagonal pattern, where six tires surround a central tire. This modular design covers large areas and maintains structural integrity by bolting neighboring tires together with steel bolts. The assembly process occurs in two phases:

1.Ground Assembly: Tires are bolted together on the ground to form the grid.

2.Tensile Network Formation: Certain tires are anchored to the ground with cables and attached to poles, allowing the structure to be elevated and shaped by adjusting the tension in the cables.

This system provides both flexibility and stability, making it ideal for creating adaptable pavilion structures that can withstand environmental challenges like wind loads while accommodating various uses (Figure 2).

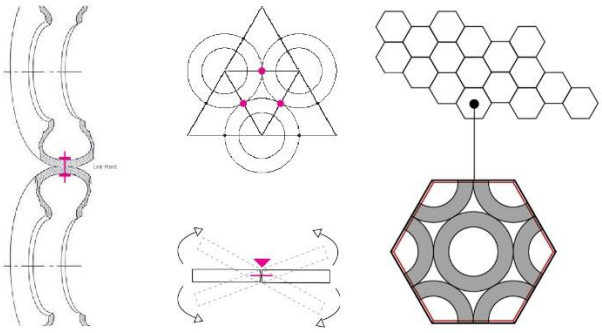

Figure 2: *(left) a cross-section of connection points and resistance around the torque point, ensuring structural integrity. (right) the hexagonal tire grid system*.

Design process: To model the tire grid, design tools like Rhino are used to create a parametric model with a repeated hexagonal grid (1.3-meter sides) covering 4.39 square meters covering 1,624.5 square meters, using 1,159 recycled tires. In the second phase, the shapes are defined and input into Grasshopper for analysis and testing using the Kangaroo physics engine, helping determine the structural elements of the pavilion (Figure 3).

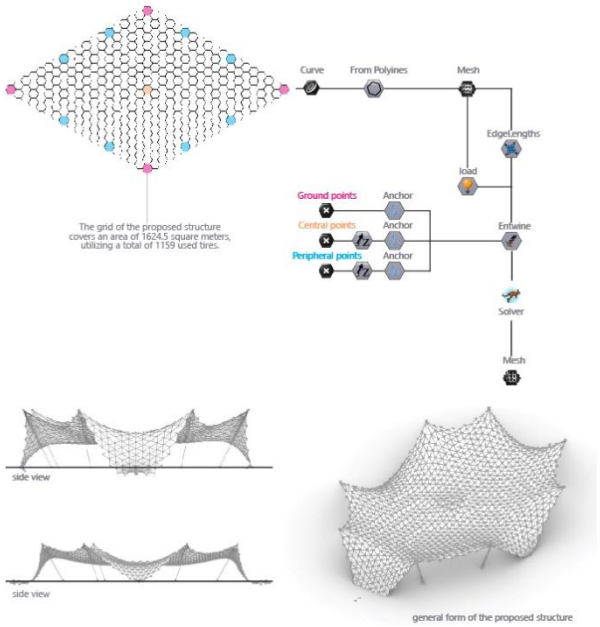

Figure 3 : *creation of the hexagonal grid and the distribution of anchor points (ground, central, peripheral) to ensure structural stability.*

Fabrication and assembly: The assembly process consists of three main steps. First, the tires are arranged

according to the grid and secured together to form the tire fabric. Next, the edge tires are anchored, and tension poles are fixed to the ground. Finally, tension is applied, and the fabric is lifted to form the pavilion structure. This process resembles the traditional method of setting up an Arabian tent, making it familiar and accessible for local communities in Nouakchott.

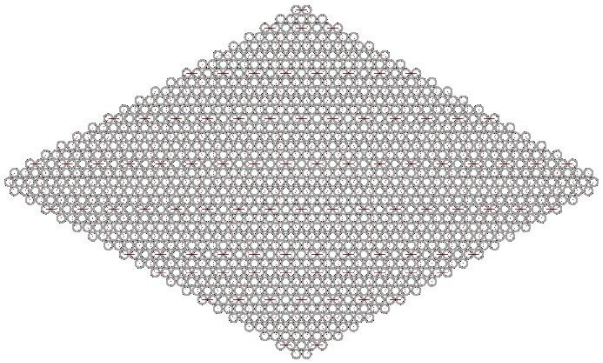

Figure 4 : *creation of the hexagonal grid and the distribution of anchor points (ground, central, peripheral) to ensure structural stability.*

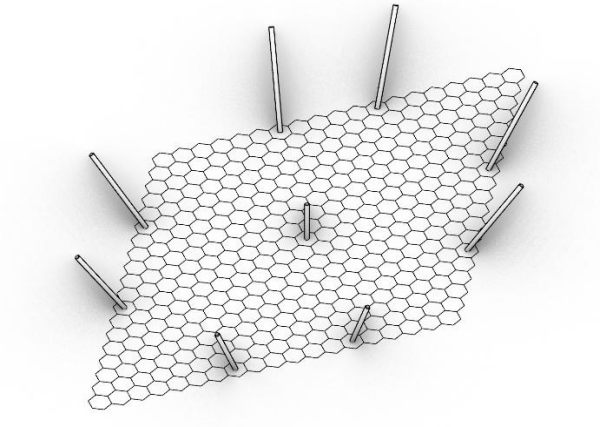

Figure 5 : *second phase where edge tires are anchored, and tension poles are securely fixed to the ground..*

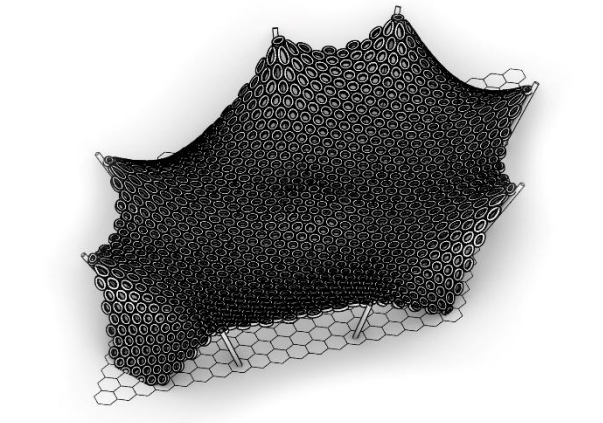

Figure 6 : *third phase, where cables are tensioned to lift the tire fabric into its final shape*

4. THE RESULT

The 3D visualizations provide a clear understanding of the construction process, showing how the final structure integrates with its surroundings. They illustrate the practical application of design concepts, emphasizing structural details and the pavilion's functional benefits in an urban context.

Figure 7 : *form of the pavilion. shows the contrast between the shaded interior and bright exterior*

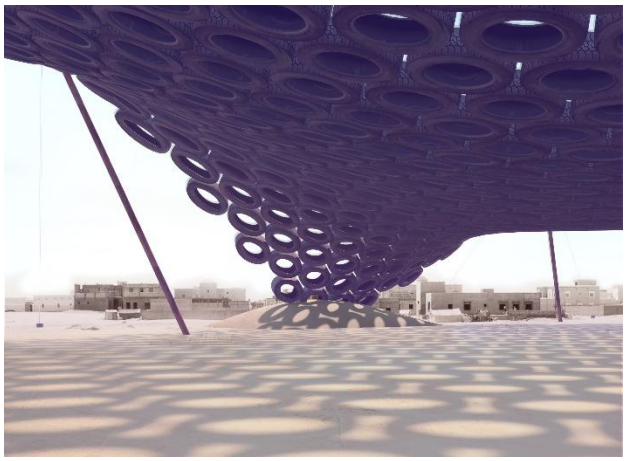

Figure 8 : *pavilion's interior, where recycled tires create a canopy that provides shade while allowing sunlight to filter through*

Figure 9 : *aerial view of the pavilion*

4. CONCLUSION

This project presents an unconventional model for using recycled tires as a primary material in the design of sustainable, replicable architectural structures in urban environments. By integrating digital technologies such as Rhino and Grasshopper, material usage has been optimized, reducing waste while ensuring the safety and durability of the structure in challenging environmental conditions.

The research emphasized the importance of understanding the needs of local communities and involving them in the design process, with a deeper understanding of cultural and social concepts. As the primary users of the pavilion, community input significantly influenced the design phase, reinforcing the idea that sustainable solutions must be co-created with the local population.

Furthermore, the study highlighted the significance of pavilion design as a medium of communication between the architect and the community, not limited to artistic or commercial purposes. This perspective enhances the role of the architect as a contributor to improving urban and social environments.

The research concludes that pavilion structures can offer temporary environmental solutions to address rapid urban growth in Nouakchott. Not only do these structures create multifunctional shaded spaces, but they also empower local communities to develop the project further in ways that improve their local environments. These pavilions offer a flexible model that can be adapted to different environmental and social needs, contributing to enhancing the local environment and fostering environmental awareness and community cooperation.

Based on the findings, the project demonstrates great potential for replicating the model in other urban areas facing similar environmental challenges. The integration of sustainable design with community participation suggests that architectural projects can be transformed into real tools for improving quality of life in cities with limited resources and underdeveloped infrastructure..

5. LITERATURE

[1] Advances in Architectural Geometry, 2016. Available: https://www.google.rs/books/edition/Advances_in_Architectural_Geometry_2016/MCb5DAAAQBAJ (accessed in August 2024).

[2] Les Ateliers de Cergy, "Nouakchott: L'avenir pour défi, adaptation et mutation d'une ville vulnérable, Cahier de session 2014", Available: https://www.pseau.org/outils/ouvrages/les_ateliers_de_cergy_nouakchott_l_avenir_pour_defi_adaptation_et_mutation_d_une_ville_vulnerable_cahier_de_session_2014.pdf (accessed in August 2024).

[3] Steve McCurry, "Nouakchott, Mauritania", Available: https://anakegoodall.wordpress.com/2012/04/08/nouakchott-mauritania-steve-mccurry/ (accessed in August 2024).

Kratka biografija:

Muftah s.Abudajaja was born in Benghazi in 1980. He defended his master's thesis at the Faculty of Technical Sciences in the field of Architecture and Urbanism – Digital Techniques, Design, and Production in Architecture and Urbanism in 2024. Contact: m@muftah.art

Assistant Professor Marko Jovanović specializes in the application of digital techniques and design in architecture and urbanism, with a focus on the use of industrial robotics in architectural fabrication. Contact: : markojovanovic@uns.ac.rs