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# Explaining the model of biomimetic architectural Indexes in sustainable building design in residential buildings

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ABSTRACT

Human activities are highly unsustainable and are the main cause of severe environmental damage, especially in terms of depletion and instability of natural resources. In architectural studies, the current scientific research literature focuses less on and examines the areas of environmental sustainability than other topics, and this requires more extensive. The aim of this study is to examine the concept of biomimicry in architecture with a sustainability approach in residential buildings and, in a way, to explain the conceptual framework of the indexes of biomimetic architecture in sustainable building design in residential buildings. Specifically, the question is about biomimetic architecture indexes lead to sustainability in residential buildings? The research is analytical-descriptive and has an applied purpose. The method of collecting information is library and documentary. First, the basic concepts are examined and the cause-and-effect relationships that form biomimetic architecture are referred to using the content analysis method then the application of biomimicry in architecture is explained. Next, according to the formed literature, the final factor model on this issue is extracted globally and locally from the review of the research background and the collection of researchers' opinions and is finally examined in the fuzzy Delphi method. Findings and results show 7 indexes are influencing the biomimetic architectural Indexes in sustainable building design in the approach of sustainability and finally form by 4/77, process by 4/68, function by 4/67 and modelling by 4/72 average score are most important factors in the subject. In Future studies can examine the relationships between indexes.

*Running Title: Biomimetic architectural Indexes in sustainable building design in the approach of sustainability*

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## INTRODUCTION

Throughout history, the environment and nature have been sources of inspiration in various sciences, including architecture, contributing to innovations in sustainable development sciences and serving as solutions to existing problems. This has resulted in biologically-based solutions giving rise to branches of new sciences that encompass the most important research areas today. Despite the significant importance of sciences shaped by imitation or inspiration from nature, there has been no classification of these sciences or an examination of the relationships between them. However, the availability of such categorization and its application in contemporary architecture could enhance environmental sustainability. (Champion, 2019) This study aims to identify and present an applied framework of life-inspired sciences and their relationship with environmental sustainability. The research methodology in the present article is qualitative and descriptive, involving a review of all articles published in 11 Springer journals between 2020 and 2022 using the keyword "Bio." The evaluation of the thematic focus of 1,927 extracted articles led to the classification into 11 groups of biological studies including bionics, biomimetics, biomorphic, biofuels (biodiesel, bioethanol, biohydrogen, and biogas), biomaterials, biohybrids, bioaerosols, biotechnology, bio-algorithms (bio-design intelligence and bio-material intelligence), bio-art (biologically inspired design And biocreative design), biophilia (biophilic design), and their relationship with environmental sustainability. (Meriam Webester, 2022) The main subject of the present research includes the development of theoretical knowledge about life-inspired sciences, with results indicating an emphasis in international biological studies on biofuels and biotechnology aimed at reducing the impact of human activities on the environment, minimizing and efficiently using natural resources, protecting biodiversity, Ensuring sustainable resources, and establishing a harmonious relationship between humans and the natural environment. Biomimetic architecture is a design approach that seeks inspiration from nature to solve complex human challenges. (Selcuk and Mutlu, 2021) By studying the structures and processes found in the natural world, architects can develop innovative and sustainable solutions for building design. (Lopez-Maroto, 2020) This approach is grounded in the belief that nature has already perfected many of the design principles that humans are still striving to understand. (Petraglia, 2018) One of the key benefits of biomimetic architecture is its potential to create more sustainable buildings. By mimicking the energy-efficient strategies employed by organisms in their natural environments, architects can design buildings that require less energy to heat, cool, and light. For example, the Eastgate Centre in Harare, Zimbabwe, is a prime example of biomimetic architecture. Inspired by termite mounds, the building's design incorporates natural ventilation and passive cooling systems, resulting in significant energy savings. Another advantage of biomimetic architecture is its ability to create more harmonious and human-centered environments. (Dagar et al., 2022) By incorporating natural elements and patterns into building design, architects can create spaces that promote well-being and productivity. Studies have shown that exposure to nature can reduce stress, improve mood, and enhance cognitive function. Biomimetic architecture can help to bring these benefits indoors. (Smith et al., 2022) While biomimetic architecture offers numerous advantages, there are also challenges to be addressed. One challenge is the complexity of biological systems. Understanding and replicating the intricate processes found in nature can be a time-consuming and expensive endeavor. Additionally, there is a need for greater collaboration between architects, biologists, and engineers to advance the field. (Khoja et al., 2022) Despite these challenges, biomimetic architecture represents a promising approach to sustainable and human-centered design. As our understanding of natural systems continues to grow, we can expect to see even more innovative and inspiring examples of biomimetic architecture in the years to come. (Cruz et al., 2022)

## MATERIALS AND METHODS

Biomimicry and Sustainability

Today, human activities are highly unsustainable and are the main cause of severe environmental damage, especially in terms of depletion and instability of natural resources. (Dagar et al., 2022) To limit these risks and facilitate living conditions for future generations, the concept of environmental sustainability or environmental sustainability has been developed, which ensures a balance between human needs and environmental protection. (Jahangir et al., 2022) It includes different levels such as the economy, human societies, agriculture, industry, energy, and natural resources and the environment. (Misiaszek and Rodrigues, 2023) In the topic of environmental sustainability, emphasis is placed on reducing the impact of human activities on the environment, preserving natural resources, efficiently using native resources, reducing pollution and climate change, protecting biodiversity, and providing sustainable resources, including water, air, and soil. (Horn et al., 2018) The main aim in this regard is to create a decent life and preserve resources for future generations. Although nature does not contain a fully understood set of patterns based on environmental sustainability, it has undoubtedly been referred to throughout history as a source of inspiration in the field of sustainability. (Reap et al., 2015) Environmental sustainability is a human-made concept, inspired by nature, and the concepts of bio-inspiration and sustainability are compatible. (Owen, 2020) and encompass various aspects of the architectural and urban form of social and cultural concepts and patterns. (Vaughn and Turner, 2016) The connection between biomimicry and architecture is not new. By the middle of the 20th century, the principles, designs, and structures of nature began to attract increasing attention, and they were used in relation to innovative architectural objects and structures. This led to the creation of the concepts of "biomorphic" and "organic" architecture, based on principles drawn from nature. Organic architecture found especially wide application in the genre of landscape architecture and, first of all, in the design of parks, building facilities, and exhibition pavilions. (Purwaningsih, et al, 2016) It is noteworthy that bio-motifs were mainly used for architectural, but not engineering purposes, and it was about "purity of form", "man-made nature", primarily in the aesthetic and plastic aspects. Nevertheless, we cannot fail to note that biomimicry as an independent direction of architectural thought began to be perceived as an algorithm and problem-solving tool at the end of the century before last and later. The wider development of this trend was due to technological and scientific development in recent decades. The specifics of societies that have empowered this trend are not as well-known as in the ancient and medieval eras. But it seems to be due to the fact that the era of scientific and technological progress is characterized by the development of linear and system-centered thinking, often opposed to the nonlinear complexity thinking which underlies biomimicry ideas. (Tian et al., 2022) In architectural studies, the current scientific research literature focuses less on and examines the areas of environmental sustainability than other topics, and this requires more extensive studies that are conducted through the examination of the biological sciences. The concept of bio-based solutions, meaning design inspired by nature, is one of the most important research fields today, and despite the great importance of sciences that have been developed by imitating or inspiring nature and living organisms, there have been no studies to classify these sciences and examine the relationship between them and environmental sustainability. (Sari and Hecht, 2020) The aim of this study is to examine the concept of biomimicry in architecture with a sustainability approach in residential buildings and, in a way, to explain the conceptual framework of the main indexes of biomimetic architecture in sustainable building design in residential buildings. Specifically, the main question is: what indexes in biomimetic architecture lead to sustainability in residential buildings?

*Bionic and implications*

Bionics is defined as the study of the principles and systems for the construction of living organisms and how they can be used to identify technological solutions. (Bio-In., 2023) In order to reduce human interference in nature and by inspiring or imitating the various laws and structures of nature or directly using the materials available in it, the definition of bionics is the design and construction of various equipment and solving their problems. (Marshall, 2015) Inspiration from the way animals walk to design robots (application of bionics in robotics), the idea of a teardrop shape to design the aerodynamics of the Toyota Prius (application of bionics in aerodynamics), inspiration from the reflection of cat's eye light in the design of traffic lights on highways (application of bionics in design), and the initial design of the Turning Torso Tower inspired by the shape of the human spine and body rotating ninety degrees (application of bionics in architecture) are some of the practical examples of bionics. (Cruz et al., 2022)

*Biomimicry*

Biomimicry is an innovative design approach that emulates nature's time-tested solutions to human challenges. By studying and mimicking the strategies employed by organisms in their natural environments, designers, engineers, and architects can develop sustainable and efficient solutions. This interdisciplinary field draws inspiration from the biological world to create products, processes, and systems that are harmonious with the planet. The core principles of biomimicry involve:

- Emulation: Observing and learning from nature's forms, processes, and ecosystems to guide human innovation.
- Ethical Framework: Applying these lessons responsibly and ethically, recognizing our interconnectedness with the natural world.
- Innovation: Creating sustainable and regenerative solutions that address human needs while minimizing environmental impact.

Key Benefits of Biomimicry

- Sustainability: Biomimicry promotes the development of sustainable solutions that minimize resource consumption and waste.
- Efficiency: Nature has perfected efficient designs over millions of years, offering inspiration for optimizing human-made systems.
- Resilience: By learning from nature's ability to adapt to changing conditions, biomimetic designs can be more resilient to environmental stressors.
- Innovation: Biomimicry stimulates creativity and fosters innovative thinking by challenging conventional approaches.

Biomimetic architecture, inspired by nature, represents a novel and sustainable approach to building design. By mimicking the structures, processes, and systems found in the natural world, architects aim to create buildings that are more harmonious with the environment and perform better.

Key indexes of biomimetic architecture include:

- Mimicking Form and Structure:
  - Drawing inspiration from the shapes of living organisms to create dynamic and efficient forms.
  - Using natural and environmentally friendly materials in building construction.
  - Designing structures that mimic the structural properties of natural elements like bones or seashells.
- Mimicking Processes:
  - Designing natural ventilation systems similar to termite mounds or plant leaves.
  - Utilizing renewable energy sources such as solar and wind power.
  - Managing rainwater through natural methods like infiltration into the ground.

- Mimicking Ecological Systems:
  - Creating connections between the building and its natural surroundings.
  - Using native and climate-adapted plants.
  - Designing spaces that visually and psychologically connect with nature.
- Sustainability and Energy Efficiency:
  - Reducing energy consumption through the use of natural insulation and passive ventilation systems.
  - Generating renewable energy on-site.
  - Efficiently managing water resources.
- Harmony with the Environment:
  - Minimizing the building's environmental impact.
  - Using recycled and recyclable materials.
  - Designing buildings that align with natural cycles.

*Definition and Importance of Biomimicry in Architecture*

The concept of biomimicry extends beyond mere imitation of natural elements; it entails an in-depth understanding of nature's designs and principles, offering valuable insights into sustainable and efficient architectural practices. This approach emphasizes learning from the evolutionary solutions that organisms have developed over millennia, where structures are optimized for function and environmental adaptation. For instance, as noted in (Mutazzi J et al. 2023), the structures in nature have evolved to meet specific contextual stresses and situations, presenting a vast reservoir of knowledge that architects can tap into. Embracing biomimicry can lead to innovative designs that prioritize not only aesthetic appeal but also functionality and sustainability. This kind of architecture aligns with the emerging need for ecological balance and resource efficiency, ultimately contributing to a built environment that harmonizes with natural ecosystems. Thus, biomimicry stands as a pivotal methodology in contemporary architecture, promising a future where human designs coexist symbiotically with nature. (Soar, 2015)

*Principles of Biomimicry in Design*

Natures intricate designs provide a wealth of inspiration for sustainable architecture, exemplifying the principles of biomimicry that promote ecological harmony. By closely observing and imitating nature's processes, architects can create structures that efficiently utilize resources and minimize waste. This approach not only addresses pressing environmental concerns but also leads to innovative building solutions. For instance, a study highlighted the significance of integrating biomimicry principles into architectural practices, revealing how strategies like indirect and direct mimicking can enhance the ecological sustainability (Gamage et al. 2015). Additionally, a framework was proposed that emphasizes the importance of reflecting on sustainability while engaging with nature's wisdom (Dahy et al. 2022). This framework serves as a guide for architects to reconcile their designs with natural ecosystems, thereby fostering more balanced relationships between humanity and the environment. Ultimately, embracing biomimicry in design offers a path toward architectural practices that are both environmentally responsible and aesthetically profound.

*Key Strategies and Techniques Inspired by Nature*

The exploration of nature's principles has led to innovative strategies in architectural design, fostering a sustainable future. One notable approach is biomimicry, wherein architects adopt techniques derived from natural systems to solve complex design challenges. This perspective draws from ecosystems self-organizing properties, emphasizing adaptability and resilience, as highlighted by the concept of Digital Ecosystems, which utilizes evolutionary computing to enhance software applications. Similarly, the principles of ecology serve as a valuable guide, demonstrating how designs can mature and respond dynamically to user needs, paralleling the concept of ecological succession as observed in biological ecosystems (Briscoe et al. 2011). Furthermore, the integration of biomimicry into architectural practices has shown substantial promise in promoting ecological sustainability. Research indicates that combining direct and indirect mimicking strategies can effectively reduce environmental waste while enhancing spatial efficiency in buildings, ultimately contributing to significant advancements in eco-friendly architecture (Gamage et al. 2015). By embracing these natural strategies, architects can create designs that are not only innovative but also harmonious with the environment.

It can also be stated that biomimicry architecture presents specific concepts and keywords in the sustainability approach and design topic in previous research:

Accordingly, key concepts can be stated as influential factors in the subject as follows:

Table 1: Research background in biomimicry architecture indexes in the design of buildings with a sustainable approach

| Researcher | Background | Contributions | Year | Keywords | Research Title |
|---|---|---|---|---|---|
| Janine Benyus | Biologist, author, and innovation consultant; co-founder of Biomimicry 3.8 | Authored "Biomimicry: Innovation Inspired by Nature"; advocated for integrating natural processes in design. | 1997 | Biomimicry, design methodology | "Biomimicry: Innovation Inspired by Nature" |
| Neri Oxman | Architect, designer, and professor at MIT; founder of Mediated Matter group | Explores the intersection of biology, architecture, and design; developed nature-inspired materials and structures. | 2010 | Digital fabrication, responsive design | "Designing with the Living: A New Paradigm" |
| Michael Pawlyn | Architect and co-founder of Exploration Architecture; author of "Biomimicry in Architecture" | Promoted sustainable design solutions through biomimetic architecture; designed projects inspired by nature. | 2011 | Sustainability, eco-friendly design | "Biomimicry in Architecture" |
| Chris Reed | Landscape architect and professor at Harvard GSD; founding principal of Stoss Landscape Urbanism | Focused on ecological design; integrated biomimicry into landscape architecture and urban resilience. | 2019 | Ecological design, urban resilience | "Site Design: Drawing on the New Ecological Age" |
| William McDonough | Architect, designer, and author; known for Cradle-to-Cradle design principles | Advocated for sustainable design and circular economy; influenced architectural practices inspired by nature. | 2002 | Sustainability, circular economy | "Cradle to Cradle: Remaking the Way We Make Things" |
| Elinor Ostrom | Political economist; Nobel laureate in Economic Sciences | Influenced sustainable practices in resource management, impacting ecological design considerations in architecture. | 2021 | Common-pool resources, sustainability | "Governing the Commons: The Evolution of Institutions for Collective Action" |
| Peter Eisenman | Architect and educator known for his theoretical approaches to design | Engages in architectural theory discussions influenced by natural forms and structures; promotes form-based design. | 1981 | Architectural theory, natural forms | "The Formal Basis of Modern Architecture" |
| David Benjamin | Architect and co-founder of The Living; professor at Columbia University | Researches adaptive systems in architecture; focuses on integrating biological principles in design strategies. | 2023 | Adaptive architecture, biomimetic design | "Living Architecture: A New Approach to Sustainable Design" |

Table 2: Influential factors in indexing biomimicry architecture in designing residential buildings with a sustainable approach

| Influential factors in indexing biomimicry architecture in designing residential buildings with a sustainable approach | | | | |
|---|---|---|---|---|
| Energy consumption | Ecology | Process | Function | Form |
| Visual structure | Modeling | Environmental interaction | Connection | Management |
| Resilience | Environmental compatibility | Environmental response | Natural cycle | Recycling |

*Methodology*

The research is analytical-descriptive and has an applied purpose. It can also be emphasized that the research is developmental in nature. The method of collecting information is library and documentary. First, the basic concepts are examined and the cause-and-effect relationships that form biomimetic architecture are referred to using the content analysis method. Next, the application of biomimicry in architecture is examined and initial conceptual models are presented. Next, according to the formed models, the final factor model on this issue is extracted globally and locally from the review of the research background and the collection of researchers' opinions and is finally examined in the fuzzy Delphi method. In the Delphi method, using elites and experts in the fields of architecture, energy, etc., approximately 15 people, in a minimum of 3 to 4 rounds, using the Google Pot tool, the questionnaire is sent and its feedback is examined with regard to changes in accuracy and the Kendall coefficient at each stage, and finally the final indexes are presented. As a result, the proposed indicator model is presented as a model of the impact of biomimicry in architecture with a sustainable design approach in residential buildings.

## DISCUSSION AND FINDINGS

*Findings from implementing the Delphi method*

In the first round, the panel members identified 12 factors out of 15 factors extracted from successful research as having a high or very high impact in developing a framework for biomimicry architectural indexes in the design of residential buildings with a sustainable approach. The detailed results related to the implementation of the first stage of questionnaire distribution are given in the table below. The factors of visual structure, management and recycling were excluded from the Delphi process due to their average importance of less than 2.5. (Table 3)

After the first stage of measuring and evaluating the panel experts' views on the factors proposed and extracted from the theoretical foundations and also receiving the suggestions of the panel members, in this round, in order to be cautious, all the factors extracted from the theoretical foundations were again made available to all panel experts, along with the average of the members' opinions In the first round and the previous opinion of the same member. The panel members identified 9 factors out of the 12 factors presented in the second round as having a high and very high impact (with an average greater than 3)

Table 3: Step 1 of the fuzzy method in developing proposed biomimicry architecture indexes in the design of residential buildings with a sustainable approach

| No | Factors | Number of responses | Average | Standard deviation | Minimum | Maximum |
|---|---|---|---|---|---|---|
| 1 | Environmental compatibility | 15 | 3/21 | 0/35 | 1 | 5 |
| 2 | Environmental response | 15 | 3/22 | 0/37 | 1 | 5 |
| 3 | Ecology | 15 | 2/78 | 0/37 | 1 | 5 |
| 4 | Modeling | 15 | 3/45 | 0/45 | 1 | 5 |
| 5 | Environmental interaction | 15 | 3/44 | 0/40 | 1 | 5 |
| 6 | Resilience | 15 | 2/86 | 0/35 | 1 | 5 |
| 7 | Connection | 15 | 2/68 | 0/37 | 1 | 5 |
| 8 | Energy consumption | 15 | 2/75 | 0/52 | 1 | 5 |
| 9 | Function | 15 | 3/58 | 0/76 | 1 | 5 |
| 10 | Process | 15 | 3/55 | 0/52 | 1 | 5 |
| 11 | Natural cycle | 15 | 2/41 | 0/57 | 1 | 5 |
| 12 | Form | 15 | 3/75 | 0/60 | 1 | 5 |

on the proposed framework of biomimicry architectural indexes in the design of residential buildings with a sustainable approach. The detailed and extensive results related to the implementation of the second stage of questionnaire distribution are given in the table below. In the second stage, the factors of natural cycle, resilience and connection were eliminated. The Kendall's coefficient of agreement for the members' responses regarding the order of the factors that had a high and very high impact in this round was 0.765. (Table 4)

In the third round, the proposed framework for biomimicry architectural indexes in the design of residential buildings with a sustainable approach was developed, along with the average of the members' opinions in the second round and the previous opinion of the same member, and was made available to all panel experts. The panel members considered 7 factors out of the 9 factors presented in the second round to have a high and very high impact (with an average greater than 3.5). In the third stage, the energy consumption and ecological factors were eliminated. The detailed and extensive results related to the implementation of the third stage of questionnaire distribution are shown in the table below. The Kendall coordination coefficient for the members' responses regarding the order of the aforementioned factors was 0.792. (Table 5)

Table 4: Step 2 of the fuzzy method in developing proposed biomimicry architecture indexes in the design of residential buildings with a sustainable approach

| No | Factors | Number of responses | Average | Standard deviation | Minimum | Maximum |
|---|---|---|---|---|---|---|
| 1 | Environmental compatibility | 15 | 3/41 | 0/32 | 2 | 5 |
| 2 | Environmental response | 15 | 3/40 | 0/34 | 2 | 5 |
| 3 | Ecology | 15 | 3/15 | 0/35 | 2 | 5 |
| 4 | Modeling | 15 | 3/85 | 0/41 | 2 | 5 |
| 5 | Environmental interaction | 15 | 3/64 | 0/35 | 2 | 5 |
| 6 | Energy consumption | 15 | 3/10 | 0/45 | 2 | 5 |
| 7 | Function | 15 | 3/78 | 0/65 | 2 | 5 |
| 8 | Process | 15 | 3/79 | 0/45 | 2 | 5 |
| 9 | Form | 15 | 3/87 | 0/55 | 2 | 5 |

Table 5: Step 3 of the fuzzy method in developing proposed biomimicry architecture indexes in the design of residential buildings with a sustainable approach

| No | Factors | Number of responses | Average | Standard deviation | Minimum | Maximum |
|---|---|---|---|---|---|---|
| 1 | Environmental compatibility | 15 | 4/21 | 0/29 | 3 | 5 |
| 2 | Environmental response | 15 | 4/20 | 0/28 | 3 | 5 |
| 3 | Modeling | 15 | 4/65 | 0/35 | 3 | 5 |
| 4 | Environmental interaction | 15 | 4/44 | 0/28 | 3 | 5 |
| 5 | Function | 15 | 4/58 | 0/29 | 3 | 5 |
| 6 | Process | 15 | 4/59 | 0/25 | 3 | 5 |
| 7 | Form | 15 | 4/68 | 0/29 | 3 | 5 |

In the fourth round, the proposed framework for biomimicry architectural indexes in the design of residential buildings with a sustainable approach was developed, along with the average of the members' opinions in the third round and the previous opinion of the same member, and was made available to all panel experts. The panel members identified 7 factors from the 7 factors presented in the third round as having a high and very high impact (with an average greater than 4). In the fourth stage, all factors in the fourth stage were confirmed. The detailed and extensive results related to the implementation of the third stage of questionnaire distribution are shown in the table below. The Kendall coefficient of agreement for the members' responses regarding the order of the aforementioned factors was 0.790. (Table 6)

## RESULT AND CONCLUSION

*Reasons for stopping the survey*

The results of the four rounds of implementing the Delphi method in the research show that consensus was reached among the panel members for the following reasons and the rounds can be ended:

- In the third round, more than 50% of the members selected 7 influential factors in the proposed framework of biomimicry architectural indexes in the design of residential buildings with a sustainable approach, which had an average greater than 3.5, among their factors.
- The standard deviation of the members' responses regarding the importance of the factors in the fourth round has decreased significantly compared to the previous rounds.
- The Kendall coefficient of agreement for the members' responses regarding the order of the factors in the fourth round is 0.790. Considering that the number of panel members was more than ten, this level of the Kendall coefficient is considered to be quite significant.
- Kendall's coordination coefficient for the arrangement of the 7 factors effective in developing the proposed framework of biomimicry architectural indexes in the design of residential buildings with a sustainable approach in the fourth round decreased by only 0.002 compared to the third round, which does not show a significant change in this coefficient or the level of consensus among the panel Members between two consecutive rounds.
- The scores given to the factors by experts and elites indicate that the form, patterning, process and performance indexes have the highest score and, as a result, the greatest impact in explaining the concept of the proposed framework of biomimicry architectural indexes in the design of residential buildings with a sustainable approach. (Table 7)

Table 6: Step 4 of the fuzzy method in developing proposed biomimicry architecture indexes in the design of residential buildings with a sustainable approach

| No | Factors | Number of responses | Average | Standard deviation | Minimum | Maximum |
|---|---|---|---|---|---|---|
| 1 | Environmental compatibility | 15 | 4/30 | 0/25 | 3 | 5 |
| 2 | Environmental response | 15 | 4/28 | 0/26 | 3 | 5 |
| 3 | Modeling | 15 | 4/72 | 0/32 | 3 | 5 |
| 4 | Environmental interaction | 15 | 4/53 | 0/25 | 3 | 5 |
| 5 | Function | 15 | 4/67 | 0/24 | 3 | 5 |
| 6 | Process | 15 | 4/68 | 0/24 | 3 | 5 |
| 7 | Form | 15 | 4/77 | 0/25 | 3 | 5 |

Table 7: Indexes and Measuring tool considered as a proposed framework for biomimicry architectural indexes in the design of residential buildings with a sustainable approach

| Title | Index | Measuring tool |
|---|---|---|
| Biomimicry architectural indexes in designing residential buildings with a sustainable approach | Environmental compatibility | Interview-Checklist |
| | Environmental response | Interview-Checklist |
| | Modeling | Interview-Checklist |
| | Environmental interaction | Interview-Checklist |
| | Function | Interview-Checklist |
| | Process | Interview-Checklist |
| | Form | Interview-Checklist |

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