

Barriers Militating Against the Adoption of Biomimicry as a Sustainable Construction Practice

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Abstract. The integration of sustainable practices into construction processes and activities are imperative for achieving the greening agenda of the construction industry. However, there has been a proliferation of several sustainable construction practices (SCPs) with biomimicry standing out among them. As a novel approach that studies and emulates nature's forms, processes, and strategies to proffer sustainable solutions to human challenges, biomimicry is beginning to gain momentum in its application across different sectors. This research sets out to identify what constitutes the barriers to the application of biomimicry. A structured questionnaire survey was conducted to establish the perception of construction professionals on the significant barriers to biomimicry adoption and implementation. A quantitative approach to data analysis was employed using the mean scores of the identified variables. Lack of awareness, lack of professional knowledge, and lack of training and education are identified as the top three barriers to biomimicry adoption and implementation. The study recommended that government, relevant professional bodies and stakeholders should encourage and embrace the adoption of biomimicry through awareness, education, training, and inclusion in the curriculum of institutions of higher learning. These will maximise the potential of biomimicry to aid innovative and sustainable outputs in the construction industry.

1 Introduction

It is common knowledge that the construction industry (CI) globally do have a negative impact on the human environment. According to [1], the activities of the CI have replaced the forest and natural ecosystem with buildings and other infrastructural projects. Waste generation, emission of toxic air, high energy and natural resources consumption, greenhouse gas emissions and pollution are few of these impacts. As identified by [2] and [3], other negative impacts of the industry are over-dependence on fossil fuel for energy production, consumption of minerals and resources, land disposal of generated waste, and air, water, and noise pollution. These and other adverse impacts of the CI on the human and natural environment makes it a significant sector where environmental-friendly drives are imperative. Also, the will of the stakeholders to transform the industry from the traditional state towards the sustainable paradigm is essential for enhancing global competitiveness and local economic growth. Sustainability is also vital in the CI for significant reduction of the various adverse environmental impacts due to construction processes and activities.

Since the Brundtland definition, several definitions of sustainability have been found through literature. However, there is a broad acceptance among researchers and sustainability proponents that sustainability must combine and harmonize the three pillars of

environmental, social, and economic dimensions [4]. Sustainability, therefore, entails a balanced and integrated interaction between these three dimensions also known as the pillars of sustainability. By embracing sustainability, the continued existence of future generations is enabled and assured by safeguarding the human and natural environment and ensuring their progression [5]. As identified by [6], three forces are propelling the shift of the CI towards the sustainability paradigm. The first is the pressures experienced by the increasing demand for natural resources, resulting in shortages and higher prices for materials. The second is the massive and accelerated destruction of planetary ecosystems and biodiversity, alteration of biogeochemical cycles, significant increase in population and consumption, all resulting in the threat of global warming, depletion of marine life, desertification, and deforestation amongst others. Thirdly, the transformation movement coupled with the various approaches adopted in the industry towards greening their activities. These forces have led to the growing recognition and importance of adopting the principles of sustainability in the CI [7] in the form of sustainable construction (SC).

The high rate of economic development experienced in several highly populated world cities appreciably increases the impact of the CI on the environment [8], hence, the importance of SC. SC and other words such as 'high performance', 'environmentally-responsive', 'green', and 'eco-friendly' are often used

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interchangeably [6, 9, 10] to describe the transition of the CI towards the global sustainability paradigm. SC is defined as the creation and responsible management of a healthy built environment based on resource efficient and ecological principles [11, 12]. As affirmed by [13], SC aims to reduce and possibly eradicate the environmental issues associated with construction activities and the built environment while maximising their potential benefits to the society and the economy.

To achieve the aims of SC, several sustainability trends also described as sustainable construction practices (SCPs) have been proliferated by different researchers, sustainability proponents, organisations and other stakeholders. Examples of the widely known SCPs in the CI include Factor 4 and Factor 10, biophilia, ecological economics, the Natural Step, ecological footprint, ecological rucksack, eco-efficiency, biomimicry, Building Information Modelling (BIM), cradle to cradle, life-cycle assessment (LCA), life-cycle costing, design for the environment, Industrialised Building System (IBS), value engineering (VE), construction ecology, and lean construction amongst others [6, 14]. These SCPs are all as a result of the conscious and deliberate efforts of different stakeholders in the CI, geared towards the integration of sustainability principles into the processes and activities of the CI. However, a significant number of these SCPs only addresses one or at most, the combination of two dimensions of sustainability leaving out a holistic amalgamation and consideration of the three pillars. Standing out of these SCPs is biomimicry, a novel field of discipline which studies nature's models and then emulates their forms, processes, strategies, and systems to proffer solutions to human challenges in a sustainable manner [15].

This study, therefore, evaluates the barriers hindering the adoption and implementation of biomimicry as a SCP in a bid to ensure and realise the greening agenda of the CI. A review of related studies and literature on biomimicry and its sustainability potential in the CI is first presented. The next section presents the research method adopted for the study, followed by the discussion of the findings from the study. The final section provides an overview of the issues discussed in the paper, draws conclusions from the study and thereafter proffers recommendations.

2 Overview of biomimicry

In the quest for sustainable solutions to the numerous challenges facing humanity, the natural world has become a viable area for exploration of sustainable ideas and solutions. Owing to its over 3.8 billion years of evolution, nature has been able to operate, survive and sustain itself over the long haul. The highly successful research and development (R&D) lab that the natural world operates in have equipped the about 10 to 30 million existing species with the ability to do what humans want to do but in an eco-friendly manner [16]. It is discovered that nature has evolved over the years with highly efficient processes, systems and strategies which

has the potential to propel and proffer solutions to the different challenges facing humanity [17]. It is through these various discoveries about nature that biomimicry was conceptualised.

The term biomimicry originated from the Greek words *bios* (life) and *mīmēsis* (imitation) which literally means 'life imitation' or the 'imitation of life' [18-20]. It is defined as the examination and emulation of nature's systems, processes, and elements with the aim of solving human challenges sustainably [21]. Through the study of nature's models and emulation of their forms, processes, systems and strategies, biomimicry seeks to solve human challenges in a holistically sustainable manner. However, multiple terms such as biomimetics, biognosis, bionics, bio-inspiration, biomimesis, bioanalogous design, and bio-inspired design are used interchangeably by different researchers and authors in literature. There is, therefore, no fundamental and significant difference between the terms and biomimicry [22]. They all represent the creation of sustainable designs and solutions through the study and conscious emulation of natural forms, processes and ecosystems [23, 24].

3 Essential elements of biomimicry

The practice of biomimicry entails three intertwined, but cogent elements which represents the foundation of the biomimicry meme [25]. They are the *ethos*, *(re)connect* and *emulate* elements. A properly balanced application of these three elements will ensure the sustainability of bio-inspired designs and solutions which is the overarching goal of biomimicry.

3.1 The ethos element

These are elements that form the essence of intentions, ethics and underlying philosophy why biomimicry is practised. It represents human respect for, responsibility to, and gratitude for the natural world and ecosystem. Considering the vast deposit of ideas for sustainable solutions that is found in the natural world, human respect, responsibility, and gratitude is the only way to maximise and tap them for the benefit of the human environment.

3.2 The (re)connect element

This entails the practice and mindset that explore and deepen the relationship between human beings and the rest of the natural world and ecosystem. They are the elements that authenticate the understanding that, while seemingly separate, human and natural worlds are deeply interconnected. It is also important to note that both the human and the natural environment functions best and maximally when the intertwining of both is maintained and enhanced. Sustaining this relationship will therefore be beneficial for a sustainable co-existence of both the human and the natural environment. With this understanding, exploitation of the natural world for its resources will be drastically reduced.

3.3 The emulate element

This represents the elements that bring together the patterns, principles, strategies, processes and functions exhibited by nature to inform design solutions. It is about being proactive in realising the objective of human beings fitted in and functioning sustainably on earth [25]. The emulate element describes the sole purpose of biomimicry (which is sustainability) in any area of its application. As believed by biomimicry proponents, any design informed by a careful integration and utilisation of nature's principles has the ultimate potential to result in sustainable solutions

4 Levels of biomimicry

Biomimicry delivers on a triadic level (natural form, natural process, and natural ecosystems) of increasing requirements regarding sustainability [26] to achieve solutions, designs and innovations that awe in terms of their sustainable performance [27]. These levels serve as the inspirational eyes through which biomimicry is perceived and thereafter applied in proffering sustainable solutions to human challenges. The objective of holistic sustainability in biomimicry can, however, be guaranteed and achieved when applied up to the third level (natural ecosystems).

4.1 The natural forms

This describes emulating a part of the whole structure/form of an organism [28]. It is the most straightforward level of biomimicry [29]. It could be the emulation of the pattern, shape or microstructure of a surface, such as a lotus leaf, or a larger trait that can be observed with the naked eyes, such as the kingfisher's beak. Although, applying biomimicry at this level will solve a defined challenge, however, there is no assurance that it will culminate in an eco-friendly solution [30].

4.2 The natural processes

This is a deeper level of biomimicry application as it relates to the emulation of the processes operational in the natural world. It entails the study and emulation of a series of operations or behaviours exhibited in the natural world such as manufacturing, building, recycling and transportation [31]. For example, nature is known to assemble structures at ambient temperature and pressure using non-toxic chemistry (mostly water) compared to the human method of bending, melting, casting and manipulating huge blocks or raw materials at extremely high temperatures and pressures [27].

4.3 The natural ecosystem

This is the deepest and most holistic level which entails studying and emulating the behaviour and performance of natural organisms concerning their ecosystem. Natural organisms survive and sustain themselves due to their ability to operate and perform in tandem with their

natural ecosystem. Nothing exists or operates in isolation in the natural world [29], as every organism is an integral part of a biome that is also part of a larger biosphere [27]. Biomimicry application at this level, therefore, assures of a sustainable solution to human challenges as it enables human environment performing and doing what all well-adapted organisms have learned to do, which is creating conditions conducive to life and generations to come.

5 Research methodology

This study adopted a quantitative approach. The duo of primary data (using a structured questionnaire) and secondary data (literature review) was employed to present an accurate reflection of the respondent's perception of the identified barriers. The respondents surveyed are biomimicry practitioners and construction professionals namely architects, quantity surveyors, construction managers, project managers and civil engineers, all of which are duly registered with their respective professional bodies in the South African construction industry.

The questionnaire contained only closed-ended questions and is divided into two sections. Section A of the questionnaire dealt with information about the respondents' details such as professional affiliation, educational qualification, the category of organisation they are working with, and their level of experience. Section B sought the respondents' perspective on the barriers to the adoption of biomimicry. Concerning the barriers to biomimicry adoption, the respondents were asked to indicate their level of agreement to the identified variables on a five-point Likert scale (from 1= 'strongly disagree' to 5= 'strongly agree'). Each of the questionnaires were administered through a face-to-face session, which ensured that 104 out of the 120 questionnaires was completed, returned and analysed, representing a response rate of 87 percent. Mean scores of the factors and their standard deviation were tabulated and compared. According to [32], a factor is deemed significant to the study if it has a mean value of 2.50 or more.

6 Results and discussions

6.1 Background of respondents

For the gender of the respondents, results revealed that 53.8 percent are male, while females accounted for 31.6 percent. For the respondents' professional affiliation, 24 percent of the respondents are biomimicry professionals, quantity surveyors accounted for 19.2 percent, architects accounted for 18.3 percent, civil engineers accounted for 15.4 percent and 11.5 percent are either project managers or construction managers. For the respondents' educational qualification, the results showed that 54.8 percent had a master's degree, 25 percent had a bachelor's degree, 11.5 percent had diploma certificates, and 8.7 percent had a doctorate degree. Majority of the

respondents work with private organisations, representing 79.8 percent whilst the remaining 20.2 percent work with government organisations. Also, 53.8 percent of the respondents had experience that ranged from 1-5 years, 20.2 percent had experience in the range of 6-10 years, 15.4 percent had experience that ranged between 11-15 years, 5.8 percent had experience ranged from 20 years and above, and 4.8 percent represents those that had experience ranged 16-20 years.

6.2 Barriers hindering biomimicry adoption

As shown in Table 1, the mean ranking of the identified variables was tabulated to present the respondents' perception. A perusal of the results presented shows that all the 19 barriers to biomimicry assessed have mean values of more than 2.5 [32]. This is an indication that the respondents agree that all the nineteen identified variables significantly constitute a hindrance to the adoption of biomimicry as a SCP in the CI. The result further shows that 'lack of awareness', 'lack of professional knowledge in biomimicry', 'lack of biomimicry training and education', 'lack of multi-disciplinary collaboration', and 'lack of database and information on biomimicry' are considered by the respondents as the first five significant barriers to biomimicry adoption in the CI. Other identified barriers include 'lack of client demand', 'uncertainty on performance, efficiency and effectiveness of biomimicry', 'lack of biomimetic technology', 'lack of biomimicry incorporated in the university curriculum', 'lack of well-defined biomimicry approach/strategy', 'risk associated with implementation of new practices', 'lack of government support', resistance to change in adopting new practices', and 'perceived high cost of adopting biomimicry'. The above result is corroborated by the study of [26] which identifies lack of understanding of approaches and lack of biomimicry integration knowledge as top barriers to biomimicry adoption. As a novel study, the result presented represents the barriers to the adoption of biomimicry as a SCP in the CI.

Table 1. Barriers hindering biomimicry adoption as a sustainable construction practice

Barriers	Mean value	Standard deviation	Rank
Lack of biomimicry awareness	4.58	0.692	1
Lack of professional knowledge in biomimicry	4.55	0.695	2
Lack of biomimicry training and education	4.38	0.872	3
Lack of multidisciplinary collaboration	3.94	0.993	4
Lack of database and information on biomimicry	3.85	1.180	5
Lack of client demand	3.83	1.218	6

Uncertainty on performance, efficiency and effectiveness of biomimicry	3.82	1.237	7
Lack of biomimetic technology	3.78	1.238	8
Lack of biomimicry in the curriculum	3.75	1.268	9
Lack of well-defined biomimicry approach/strategy	3.73	1.279	10
Risk associated with implementation of new practices	3.73	1.209	11
Lack of government support	3.69	1.255	12
Resistance to change in adopting new practices	3.60	1.170	13
Perceived high cost of adopting biomimicry	3.54	1.238	14
Limited availability of biomimetic materials	3.53	1.299	15
Lack of incentives for adopting biomimicry	3.59	1.207	16
Potential time factor involved in the implementation of new practices	3.46	1.314	17
Lack of building codes and regulations	3.45	1.284	18
Lack of labelling/ measurement framework	3.37	1.300	19

7 Conclusion and recommendations

The natural world is a rich source of countless ideas for innovative and sustainable solutions to human challenges. Emulating the operational processes and strategies in nature such as photosynthesis, self-assembly and natural selection, among numerous others, have birthed solutions with sustainable attributes. With its adoption and implementation, biomimicry has now become the provider of timely and significant innovations in critical areas such as energy engineering where multiple-scale efficiency improvements are much required. The novelty and potential to achieve holistic sustainability in biomimicry has also seen major multinationals like Boeing, Procter and Gamble (P&G), Nike and Interface, among many others, adopting and incorporating its principles. Recorded sustainable feats achieved by biomimicry has therefore seen it become one of the potent and efficient SCPs.

With lack of awareness, knowledge, education, and training identified in the findings as significant barriers to the adoption of biomimicry, optimising its use for sustainability purpose in the CI will remain an uphill task. Hence, it is imperative to encourage biomimicry awareness through training, workshops, and integration into the university curricula and continuous professional development (CPD) programmes of construction professionals. The government should also encourage biomimicry adoption and implementation by putting in

place incentives and necessary legislation and policies. It is, therefore, recommended that a government body is established or saddled with the responsibility of fostering and overseeing the multidisciplinary collaboration and cooperation of scientists, architects, engineers, designers, and other stakeholders, which has been established, will result in novel, amazing, and sustainable solutions to the challenges experienced in the built environment of both the developed and developing nations.

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