

TALK Capability of Biomimicry for Disruptive and Sustainable Output in the Construction Industry

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Abstract. Several sustainability trends have evolved and proliferated for greening the processes and activities of the construction industry (CI). Striking among the trends is biomimicry, a novel and nature-inspired approach that seeks a sustainable solution to human challenges by emulating time-tested patterns and strategies in nature. This study sets out to evaluate biomimicry potentials for sustainable outputs in the construction industry. An extant review of the literature was conducted on nature-inspired approaches for sustainable and innovative solutions. Findings revealed technology readiness, awareness, leadership competence, and knowledge (TALK) as critical areas where biomimicry will offer a unique step-by-step path to disruptive outcomes and potentially aid the greening agenda of the construction industry.

Keywords: biomimicry, built environment, innovations, nature, sustainability

1 Introduction

Globally, the construction industry (CI) is a major sector that aid economic stability and growth, especially in developing nations. Critical infrastructures such as roads, energy production, transmission and distribution plants, rails, bridges, and educational, commercial, residential and industrial buildings among many others are direct beneficial impacts of the CI [1]. Humanity has significantly benefitted from the provision of these infrastructures which has, in turn, contributed significantly to urbanisation and the economic growth of nations, especially the developing ones [2, 3]. Generally, it is of the belief that there is a causal link between the CI and economic growth in developing and developed countries with a focus on infrastructural developments and industrialisation. In New Zealand, the industry is recognised as one of the most significant sectors of the nation's economy, accounting for 8 per cent of the total employment [4], while accounting for another 8 per cent of the total workforce in Malaysia [5]. In developed countries of the world, the CI contribute

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significantly to the gross domestic product (GDP) and employs a notable portion of the population. Therefore, the CI is not only an indispensable fraction of the modernisation process; its adoption in developing countries as a strategy for employment creation due to its labour-intensive nature [6], attest to its global importance.

Virtually all the products of the CI, have a prolonged impact on the human environment and the ecosystem due to their continuous emission of a significant amount of pollution [7]. The use of plants and equipment to achieve project objectives is also on the increase [8], as their exhausts and emissions during operation is another contributor to the pollution of the environment. A report by the United States Environmental Protection Agency (USEPA) revealed that the indoor air levels of many pollutants may be 2.5 times and occasionally more than 100 times higher than outdoor levels [1]. These pollutant concentrations are those within buildings and emanate from backing materials, finishes, paints, and other components. Also, literature has identified that the atmospheric release of greenhouse gases (GHGs) and other emissions caused by construction activities, remains a significant contributor to ozone layers depletion, global warming and climate change. For instance, 50 per cent of the carbon emissions in the UK is traceable to the CI [9], while in China, 1260 million tons of carbon emissions associated with energy use in buildings was reached in 2008 [10]. In addition to air, water and land pollution, the CI generates a significant amount of waste from the manufacturing process and use of construction materials. As reported by Azis et al. [2], an assessment of material waste generated was carried out on a construction project in the Netherlands. The findings revealed that the quantity of materials wasted on the site is relatively high and equals to 9 per cent by weight of the purchased materials originally [2]. The sustainability issue is therefore imperative to curtail the adverse environmental impact of the CI.

Numerous interpretations of sustainability have emanated since the Brundtland definition. However, it is common knowledge and globally accepted that sustainability must encompass at least, three dimensions which are the social, economic, and environmental pillars [11]. Sustainability entails the balanced utilisation of the natural resources in a way that they do not reach the state of deterioration, attenuation and a non-renewable state and can be passed on to the coming generation [12]. According to Kibert [13], three forces propel the shift towards sustainability. Firstly, the pressures experienced by increased demand placed on natural resources, resulting in the paucity and high materials cost. Secondly, the massive and escalated destruction of the natural ecosystems and biodiversity, modification of biogeochemical cycles, a significant increase in consumption rate and population size, all resulting in the threat of global warming, depletion of marine life, deforestation, and desertification, amongst others. Thirdly, the transformation movement coupled with the various approaches adopted in agriculture, tourism, medicine, manufacturing, and other sectors, towards greening their activities and processes. These have, however, led to the growing recognition and importance of embracing and implementing the tenets of sustainability in the CI [14].

Throughout literature, terms such as ‘sustainable construction’ (SC), ‘green’, ‘environmental-friendly’, and ‘high-performance’ are interchangeably utilised [2, 13, 15], to describe the creation and responsible management of a healthy built environment based on efficient resource use and ecological principles [16, 17]. Sustainable construction (SC) aims to maximise the potential benefits accrued to the economy and society at large by the reduction or elimination of environmental challenges associated with construction processes and activities, and the built environment [1]. Other aims can be inferred from the principles of SC as presented by different authors. An international construction research organisation, the Conseil International du Bâtiment (CIB), proffered seven principles as guidelines for the integration of SC to aid the decision-making process during the entire lifecycle of a building. According to Kibert [13], the principles are: a reduction in resource consumption (reduce);

reuse of resources (reuse); use of resources with recyclable attributes (recycle); protection of the natural environment (nature); toxics elimination (toxics); application of life-cycle costing methodology (economics); and focus on quality (quality). These principles are applied when carrying out a sustainability assessment of the elements and other resources required for construction [18]. Not only do these principles apply across the lifecycle of construction (planning to deconstruction), they are also applicable to the resources (materials, land, ecosystem, water, and energy) required for creating and operating the built environment throughout its lifecycle.

Terms such as the Natural Step, ecological rucksack, ecological footprint, biophilia, ecological economics, Factor 4 and Factor 10, eco-efficiency, and biomimicry among many others have emerged and are utilised in describing the all-embracing philosophy and scientific concepts that apply to a conscious transference towards the sustainability paradigm [13]. Outstanding among these sustainability trends is biomimicry. As a relatively new field of study, biomimicry encourages the teaming up of biologists with designers and professionals from various fields (industrial design, medical science, material science, architecture, and interior design) to study and emulate the procedures and strategies operational in nature for sustainable solutions to the challenges facing the human or built environment. This paper, therefore, evaluates and presents the potentials of biomimicry for sustainable and innovative solutions in the CI. A literature review of related studies on biomimicry and novel sustainable solutions borne out of its adoption and implementation was done and presented. Presented in the final section of the paper is an overview of the issues discussed in the paper alongside the conclusions drawn and recommendations proffered.

2 Overview of Biomimicry

Historically, humanity has been dependent on the natural world to meet their shelter, and food needs and generally for survival. Due to human observation of nature and natural phenomenon, there are native innovations and developments in the areas of weapons and defence mechanisms; processes related to manufacturing; shelter architectures; agriculture and food production; and medical and pharmaceutical sciences [19]. As a result of its more than 3.8 billion years of existence, nature has become an exceptional blueprint for innovative solutions that encompasses efficiency, resource utilisation, collaboration, and longevity [20]. The application of nature-inspired knowledge to meet human needs is therefore not a contemporary practice, whereas, the term describing it is relatively new.

The concept of 'biomimicry' was widely circulated and popularised through the book *Biomimicry: Innovation Inspired by Nature*. The book was published in 1997 and authored by Janine M. Benyus (referred to as biomimicry founder), a biologist and co-founder of the Biomimicry Guild [21]. However, throughout literature, multiple terms are used to describe this practice of emulating and learning from the natural world to solve human challenges. As affirmed by Aziz and El Sheriff [22], the terms 'biomimetics' and 'biomimetics' fundamentally shares the same meaning, noting that other terminologies like bioinspiration, bionics, nature-inspired design, bioanalogous design, biomimesis, biognosis, and bio-inspired design are often used interchangeably with biomimicry and biomimetics [23-25].

Also, the term biomimicry came from the amalgamation of the Greek words *bios* (life) and *mīmēsis* (imitation), which literally means the 'imitation of life' or 'life imitation' [19, 26]. It is described as the study and emulation of natural forms, systems, strategies, processes, operations and elements with the potential to resolve human complexities and issues in a sustainable manner [27]. Biomimicry entails proffering design solutions with sustainable attributes through the study and conscious emulation of forms, processes, and ecosystems in nature [28].

3 Biomimicry Potentials for Sustainable Solutions

Biomimicry keeps attaining immense importance as a global and popular sustainability trend in planning for eco-friendly developments typified by its capability to trigger unconventional innovations and breakthroughs (25, 29). It is also understood by many as a branch of biological science going by the term. However, the scientific knowledge encapsulated by biomimicry only aids the ingenuity of learning about and from nature [30]. It heralds a shift from human's exploitative era of extracting from nature to mastering the attributes that support its evolution and survival over the years [31]. While biomimicry can be employed specifically as a method of improving the eco-friendliness of what is existing [29], it can also be used in developing sustainable innovations and technologies as well [32]. Biomimicry potentials for sustainable innovations and outputs in the CI are, therefore, presented in the areas of *technology readiness, awareness, leadership competence, and knowledge* (TALK).

3.1 Technology Readiness

Biomimicry proponents believe that the CI needs to examine the exceptionally successful 3.8 billion years of research and development (R+D) lab that the earth operates. Here, about 10-30 million organisms have mastered and perfected doing everything human intend to accomplish, without causing environmental pollution, or mortgaging the fortune of future generations [33]. Owing to these strategies employed by nature to evolve and sustain itself over the years, innovations, ideas, and solutions inspired by nature are now believed to be the panacea to the challenges facing humanity.

Biomimicry has now taken the frontline of technological and scientific research because of its potential to propel new ideas for the invention of sustainable solutions and technologies [34]. Also, the study and application of biomimicry have been observed in a broad range of fields such as material research, aerodynamics, communications, architecture, transportation, human safety, products design, and mechanics [35, 36]. Many researchers have investigated bio-inspired (biomimetic) materials and technologies in the construction and built environment (C&BE). Based on their application, the materials and technologies are found to have advantageous attributes such as low weight and reduced manufacturing costs compared to traditional ones [37]. Other researchers seek new pathways to achieve novel construction materials and technologies with sustainable properties in line with the biomimicry paradigm, thus leading to the revelation of more remarkable characteristics such as self-repairing, self-organising, self-cleaning, self-healing amongst others [38]. Bio-inspired adhesives and coatings, self-cleaning finishes, biotechconcrete, and energy conversion and conservation technologies are few of the numerous successes recorded with the application of biomimicry. Table 1 shows a few of the existing biomimetic technologies and materials that can be applied and utilised in the CI.

Table 1. Biomimetic materials and technologies applicable in the construction industry.

Product	Source of Inspiration	Function
Eco-Cement	Sea Snail	Neutral and strength-enhancing carbon-sequestering cement
Self-repairing Concrete	Pipevine, human skin, cells, vertebrates bone	Self-repairing concrete that increases the durability of structures and reduces life-cycle cost
Lotusan® Paint	Morpho butterfly, sacred lotus	Automatic self-cleaning coat after the mere rinse of a rain shower
Lotus Clay Roofing Tiles	Morpho butterfly, sacred lotus	Self-cleaning clay roof tiles/coverings
Dye-Sensitised Solar Cells and Panels	Cooke’s koki’o (photosynthesis)	Low-cost and efficiently produced electricity by artificial photosynthesis
ORNILUX Insulated Glass	Orb-web spider	The insulated architectural glass that prevents bird collisions
Biolytix® System	Soil ecosystem	Waste treatment and water filtering system
Eco-Machine	Forests	Wastewater treatment system that purifies water without chemicals
Purebond	Blue mussels	Formaldehyde-free wood glue
I2™ Modular Carpet	Forest floor	Individually replaceable and recyclable carpet tiles

Source: [46].

3.2 Awareness

It is imperative to be aware of the principles underlying the application of biomimicry, to maximise the potential benefits accrued to its adoption and implementation of in the CI. For biomimicry to attain its overall target of sustainable and innovative solutions, Goss [21] advocated that asking the following questions is pertinent: Does the design integrate cycles? Does it heal after a disturbance? Is the design locally attuned and responsive? Is it informed by local inhabitants of all species? Is it resourceful and connected to local feedback loops? Does the design integrate cycles? Does it adapt to seasons, reuse materials, and maintain itself through turnover? Does the design leverage its interdependence in the system? Is the design resilient? Can it withstand disturbance while maintaining function? Does it fit form to function? Does the design optimise rather than maximise? Does it reuse materials or use recycled materials? Does the design use benign manufacturing? Is the reaction done at standard pressure and temperature? Does it enhance the system’s capacity to support life long-term? Is its success based on whether it contributes to the continuity of life?

These questions are deductions from the basic principles underpinning the concept of biomimicry, also referred to as nature principles. According to Benyus [20], these are the canon of laws, principles and strategies divined from nature’s notebooks. They are abstracted biological systems and strategies, some of which are self-explanatory and obvious, and can be found in most of the organisms, enabling life to successfully regenerates itself [39]. They are also the creative common tools and checklists which aids the sustainability evaluation

of biomimetic designs, materials, technologies and application [40]. Resonating in the book *Biomimicry: Innovation Inspired by Nature* authored by Benyus [20], nature principles are:

- Nature taps the power of limits.
- Nature curbs excesses from within.
- Nature demands local expertise.
- Nature banks on diversity.
- Nature rewards cooperation.
- Nature recycles everything.
- Nature fits form to function.
- Nature uses only the energy it needs.
- Nature runs on sunlight.

3.3 Leadership Competence

With nature as the underlying concept of biomimicry, the proponents lead the advocacy that human should relate to nature as a *model*, *measure*, and *mentor*. Based on this ideology, designers, professionals, and other stakeholders will be equipped with the requisite capacity to apply biomimicry to increase the sustainability of existing creations and to produce novel designs, materials, technologies and inventions with sustainable attributes. With nature as a *model*, inspiration is drawn from nature's forms, strategies and systems to tackle challenges in a sustainable manner [27]. Seeing nature as a *measure*, human innovations, designs and solutions will be evaluated for sustainability against standards exhibited in nature through their over 3.8 billion years of evolution [41]. With nature as a *mentor*, a purposive and deliberate human intent to learn from and develop a joint correlation with the natural world is employed, backed by the responsiveness that nature is an integral part of the human environment. These three herald a contemporary way of perceiving and evaluating the natural world thereby introducing an era based on what we can study, learn and emulate from it [31].

3.4 Knowledge

Two primary approaches exist in the application of biomimicry for sustainable interventions and innovative solutions to human challenges. They are the *problem-based approach* and the *solution-based approach*. These approaches are the dimensions through which knowledge is transferred in biomimicry application for sustainable and innovative outputs that are genuinely biomimetic [42]. Biomimicry proponents believed that these approaches would aid the steps towards transiting the built environment to a sustainable and resilient state [43, 44], as it helps proffer solutions to identified challenges and the creation of novel materials and technologies. Also, the approaches offer unique step-by-step paths under the larger umbrella of biomimicry [45]. The sole aim of these approaches is to proffer methodologies through which biomimicry can be integrated into different professions to arrive at a sustainable, efficient and effective solution.

The problem-based approach entails drawing inspiration from nature for solutions by first defining the problems and then pairing such problems with organisms in nature that have resolved similar problems. This approach endeavour to find a sustainable solution to an identified problem. Aquaporin membrane technology and Watreco Vortex Generator are examples of breakthroughs recorded with the application of this approach as a result of water treatment and purification issues. On the other hand, the solution-based approach involves identifying an attribute, behaviour and function in an organism or ecosystem and then translating it into design solutions or innovation [29]. This approach is at the forefront of providing amazing and sustainable inventions and innovations. An example under this

approach is the Mercedes-Benz bionic car which was inspired by the shape of the boxfish which controls water movement around its body to influence stability and manoeuvrability [46, 47].

4 Conclusion and Recommendations

The natural world has been existing for around 3.8 billion years with models that manufacture without heat, beat, and treat; ecosystems powered by sunlight and create design solutions rather than waste. As observed and discovered, the activities, processes, strategies, and systems displayed in nature are found to be sustainable, effective, efficient and aesthetically pleasing too. These, among other attributes, has made biomimicry to be outstanding among the sustainability trends applied in the CI and other sectors.

Biomimicry has already instituted the realisation of some appropriate and exceptional innovations in different sectors and specific areas of global interest such as energy engineering and waste re-use, where multiple-scale efficiency improvements are much needed. Examples include the noiseless Shinkansen Bullet Train (inspired by the splashless water entry of kingfishers and silent flight of owls), the smart-windows and walls called RavenBrick (inspired by passive pigmentation in cephalopods and many species of lizards), wind energy harvesting Vibro-Wind without turbine (inspired by the movement of leaves in windy condition), and Green infrastructure stormwater control (inspired by the filtering mechanism provided by the vegetation in an ecosystem) amongst others.

Also, the Biomimicry Guild, now named Biomimicry 3.8, which is the world-leading bio-inspired consultancy organisation co-founded by Janine M. Benyus, has collaborated with major multinational companies and corporations to apply the knowledge of biomimicry (nature-inspired strategies) in creating sustainable and innovative solutions. Few of these corporations include Nike, Procter and Gamble (P&G), Interface (carpet company), Boeing, Colgate-Palmolive, Coca-Cola Company, Hewlett-Packard, HOK architects, Kohler, and Shell. It is therefore pertinent to ensure the holistic application of biomimicry to arrive at a sustainable outcome which is the sole target of this new field. Also, a multidisciplinary collaboration among designers, engineers, architects and other stakeholders should be encouraged if numerous sustainable and disruptive innovations are to be birthed to militate the adverse environmental impacts of the CI.

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