Construction of Green Buildings – A Conceptual Framework for Sustainability Implementation

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Abstract. The construction industry is facing increasing pressure when it comes to the impact of construction technology, the use of natural resources in the construction and maintenance of buildings after construction, as well as the sustainability of buildings. Measures introduced by leading countries and experts in the fight against the impact of harmful gas emissions on the environment also concern the construction industry, which is ordered to improve its impact on the natural environment in the future, i.e., to begin the era of the so-called green buildings, which will help slow down the global warming process on the planet. This paper will explore the existing conceptual framework for sustainability implementation in the fields of architecture and construction. The research was conducted by reviewing the relevant literature published by experts around the world who have published scientific and research papers on this topic. The objectives of this paper are to provide principles that most authors in different countries and cultures agree on when it comes to green building construction.

Keywords: Green building · Construction industry · Design principles · Sustainability

1 Introduction

A green building is a term that is used for the building which reduces or eliminates negative impacts on our environment and climate conditions, i.e., has a positive impact because improving quality of life and preserving natural resources of our environment. In a practice any building can be a green building; schools, hospitals, houses, etc., if their design follow sustainable building features [1].

One of the definitions of green building that can be found in literature describes this type of buildings as philosophical and technical foundations in construction ecology [2]. In the same book, the term "sustainable construction" is described as the most comprehensive term for all activities that are being involved in the integration of the built with the natural environment. Also, the authors compare this type of construction with the creation of a healthy built environment respecting ecologically sound principles.

The concept of sustainable development can be described as improving the quality of life that is directly connected with present and future generations, in a sense that architects according to the improvement of quality of life enable generations to live in a healthy

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environment and improved social, economic, and environmental conditions [3]. Energy-efficient buildings (new constructions or renovated existing buildings) can be defined as buildings that are designed to provide a significant reduction of the energy needed for heating and cooling, independently of the energy and of the equipment that will be chosen to heat or cool the building. The Energy Performance of Buildings Directive (EPBD) requires all new buildings from 2021 on (public buildings from 2019 on) to be nearly zero-energy buildings (NZEB), which means a building that has a very high energy performance. The primary energy requirements of nearly zero-energy buildings (NZEB) vary between 0 and 160 kWh/m^2 a for residential buildings.

It is important to mark at the beginning of this paper that buildings are one of the largest consumers of energy. If energy efficiency is increased, in addition to reducing emissions, energy poverty would be solved, economic recovery would be improved, and people's vulnerability to energy prices in the market would be reduced [4].

According to NASA and the National Oceanic and Atmospheric Administration, it is announced that 2016 was the hottest year recorded ever, and how human activities have warmed the Earth in the past 50 years [5]. According to this article and the opinion of the author, a green building can contribute positively to climate change because its design considers energy, water, indoor environment quality, material selection, and location. Building operations together with building materials and construction generate nearly 40% of annual global CO_2 emissions [6].

Due to the above, the construction of the green building is more than ever the focus of interest of various authors. This paper will explore the existing conceptual framework for sustainability implementation in the fields of architecture and construction. The research was conducted by reviewing the relevant literature published by experts around the world who have published scientific and research papers on this topic. The objectives of this study are to provide environmental, economic, and social principles that most authors in different countries and cultures agree on when it comes to green building construction. Besides the mention, this paper also brings a conclusion of literature review related to the principles of right material decisions for implementing the best results in designing a green building.

2 Architectural Design and Sustainability Principles

There is a worldwide need for sustainable development, which strongly encourages the importance of hiring architects to create a good contemporary design, who will bring original design solutions to ensure exceptional architecture that respects the context in which is built while respecting the principles of sustainable development and expressing visual needs of the next generations. This type of design has to meet different design objectives, such as comfortable indoor climate, healthy environment, life-cycle costs, resource use, environmental loading, functionality, and architectural expression which must be adopted from the very early stages of the design process and must ensure close cooperation among the design team where are beside architect also other engineers included [7]. Green buildings are designed and have in aim to be constructed following the sustainability framework such as a balance between environmental, economic, and social principles [8]. Mentioned authors proposing framework based on the following:

resource conservation, cost efficiency, and design for human adaptation. The authors of this paper will adopt these three principles and make a literature review of the same.

2.1 Environmental Principles: Resource Conservation

Environment principles include a building that preserves nature and uses renewable resources for building. This means that materials that can be found locally always bring environmental benefits in a manner to helps lessen the environmental burdens, and shortens transport distances, thus reducing air pollution produced by vehicles. The most important for further conservation is the fact that local materials fit in the climatic condition of the area where they are excavated or found. Besides a positive impact on the environment, these purchases support area economies [8]. The sustainable design needs to support efforts in the relationship between soil, water, plant communities, and associations that deal with this issue by showing more respect for the landscape, but also to point out the importance of the impact of human use of these resources [9]. Environmental performance could be improved by selecting sustainable materials and by supporting products substantially [10]. Improving the environment through sustainable design and the green building must include strategies for efficient use of water, material, land, and energy [9, 10]. They are proposing methods for energy conservation such as smart choice of materials and construction methods.

Literature Review Findings. Summarizing the literature, the authors of this paper are listed in Table 1. Strategies and methods to achieve resource conservation.

Table 1. Strategies and methods to archive resource conservation – literature review findings.

Efficient use of	Methods
Materials	*Smart Waste Management* *Selection of Green Materials: durable, non-toxic, and local materials with the potential to be reused or recycled or already used or recycled materials* *Design for Pollution Prevention*
Land	*Adaptation of existing buildings to new uses: Building in an existing built environment or building in non-arable land Incorporation into nature*
Energy	*Developing an energy-efficient technological process* *Passive Energy Design: Natural heating and cooling with minimal losses and the use of alternative energy sources; Green material selection to reduce energy in production, conservation, and demolition*

Ambient and Orientation. The first written reference for building orientation and passive solar principles was by socrates about 2300 years ago [11]. Socrates wrote: “Now in houses with a south aspect, the sun’s rays penetrate the porticos in winter, but in the summer the path of the sun is right over our heads and above the roof so that there is shade. If then, this is the best arrangement, we should build the south side loftier to get the winter sun and the north side lower to keep out the winter winds.”

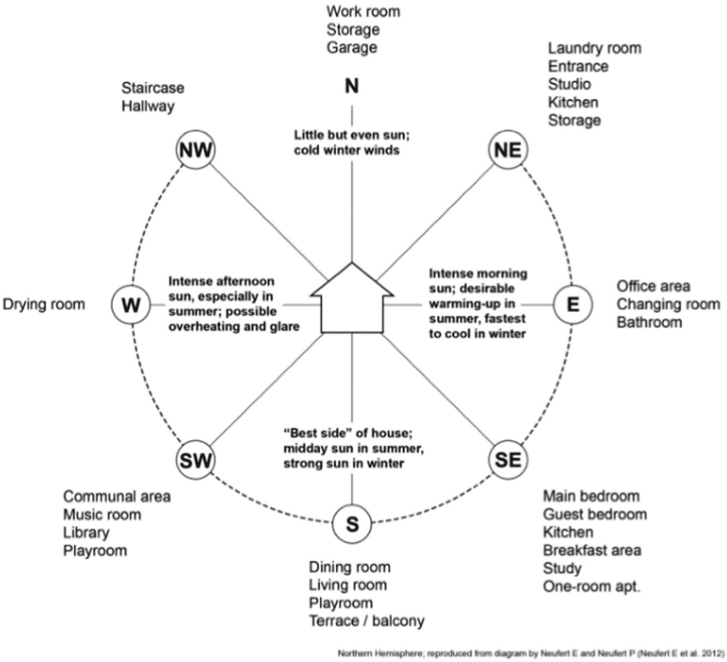

Fig. 1. Room orientation related to the movement of the sun throughout the day (Northern Hemisphere) [12].

Following the trajectory of the sun described in Fig. 1, which is important when planning the orientation of buildings and spaces within them, there are general rules that require that the south-facing rooms will have good daylight and will benefit from solar radiation throughout the year. On this side of the building, it is necessary to plant deciduous trees, which will shade and protect from the sun's rays in summer, and in winter will allow the penetration of sunlight, which will naturally heat the space. The areas in the south are very well sunny in the morning, but for energy efficiency, vertical shading must be planned to protect against overheating. When it comes to the western orientation, the same rules apply as on the eastern side of the building, except that it is about strong sun rays in the afternoon. In the northern orientation of the building, care must be taken to plant trees in front of the building, for protection from cold winds [13].

The overall energy efficiency of a building depends also on the solar orientation because it is supposed that a properly oriented building can save money by reducing 85% heating and cooling costs. Also, there is a suggestion to orientate the building on the way that the main long axis of the building, with the most glass surfaces, is East-West or rotate mentioned sides for a maximum of 20 degrees. It is important to include in the design a position of the landscape features such as trees and walls that must be in the way to make a shadow in the summer and allow the sunlight in the winter [14]. However, when it comes to the tropics, a north-south orientation is recommended as this ensures that the building takes advantage of winds that will naturally help with cooling and thus prevent excessive sunlight from the east and west causing overheating [15]. "Green" envelopes of buildings are one of the ways to create energy-efficient buildings, i.e. to save energy and contribute to mitigating energy losses. The shade effect given by plants is the most important parameter in this case [16]. Applying green facades could make an effect on the building behavior, especially if the green façade is positioned in the right orientation. A case study based on a building block in Barcelona, Spain, has proven that the north and west green façade show lower performance than other orientations [17]. According to this study, southeast and southwest-oriented green facades reduced their energy consumption by 28%., i.e. energy cost per year could be decreased with a green façade in the southeast orientation while this decrease is 18% for the southwest orientation. Also, this study concludes that choosing the proper orientation of a green façade as a final layer on the building exterior could significantly affect the quantity of ventilation in the building which is also an important effect on the quantity of energy consumed.

Literature Review Findings. Nature has its laws whose correct interpretation helps to build buildings that are energy efficient. Each building needs to adapt to the actual conditions on the ground, neighboring facilities, and the direction of the prevailing winds. Recognizing the orientation of buildings, the ambient in which they are built, as well as the features of green facades are crucial when creating green building projects.

Reusing and Recycling Materials. The construction industry, although contributing to the overall socio-economic development of each country, is a major exploiter of non-renewable natural resources and pollutants contributing to environmental degradation through resource depletion, energy consumption, air pollution, and waste generation [18]. Yearly, around 120 million tons of waste are produced by the construction, demolition, and excavation, while only half of it is recycled or reclaimed [18].

Two principles prevail in waste reduction: first, to reduce the quality of waste generated, and second, to adopt an effective management system for unavoidable generated waste. The effective management system includes three referral options, namely 'reuse', 'recycle' or 'disposal'. The balance between the three will depend on the nature of the materials that are wasted. The cost, in turn, will depend on the availability of reusability and recyclability and the possibility of reuse on a particular project [19]. The observation of construction sites of conventional buildings showed that more attention to reuse or disposal is paid to materials that impact the budget, such as steel from metal formwork which had a recovery level of about 100%, while timber formwork had only 50% [18]. Green building design includes at the beginning plan for reducing waste, such as using less raw materials if possible. If the construction firm is responsible for the waste and if there is a possibility of making their supply chain closed, then we can expect that they will reuse those materials and remanufacture products on their own site. There is an alternative solution such as selling those secondary materials [20].

Unlike the traditional demolition, the reuse of building materials in a manner of functional components such as bricks, tiles, or windows, presents an alternative to reducing construction and demolition waste in the renovation and demolition of buildings, performing deconstruction of the building [21]. A designer must consider whether any material or component of a building can be used when it comes to deconstruction [8].

Literature Review Findings. Reusing or recycling materials must be a prerequisite when it comes to preserving the environment; the suggestion is to reuse materials or components to reduce waste and save energy for the production of materials, transportation, and the like.

Materialization: Selection of Green Materials. Materials used for green building must reduce final production costs but also reduce environmental impacts. That is the main reason for the review of materialization under environmental principles in this paper [9]. Authors in the mentioned study used sustainable assessment criteria (SAC) identified based on the sustainability triple bottom (TBL) approach but also literature review in the field of material selection in combination with the requirement of project stakeholders. They conclude, after extensive research, that there are 6 most important components in the selection of green materials, i.e materials for the construction of green buildings: environmental impact, resource efficiency, waste minimization, life cycle cost, performance capability, and social benefits.

Classification of the components important for the selection of materials for the construction of green buildings is divided into three categories, economic, environmental, and social principles, i.e points of view. Waste management, water consumption, and potential for recycling and reuse are priorities under environmental criteria, while the life expectancy of materials, meeting stakeholders' needs, and operation and maintenance costs are the most important in the economic sense. The social point of view ranked health and safety as a top priority, but local material use and labor availability followed, according to the opinion of eight experts involved in developing these conclusions [22].

When it comes to resource conservation, in addition to all the above, it is believed that improving the efficiency and effectiveness of material flow can bring economic benefits [18].

Literature Review Findings. Literature review about the selection of green materials shows that materials must be sustainable – materials with a potential to be reused or recycled as an answer to positive environmental impact, in order to reduce waste but also save energy and other resources, which directly leads to the field of cost efficiency – the economic principle of green buildings.

Technology Performance: Green Structures. There are more and more architectural examples every day of how green construction is performed, as more and more professional literature is available that describes the techniques of construction of such facilities and gives guidelines on how to maintain them. Below is a review of the literature on parts of green building and how to perform them.

Green Roofs. The forerunner of green roofs, known as man's habitat in the earliest history of architecture, were dugouts and caves covered with vegetation [23]. Green roofs of modern architecture are performed in layers where the final layer is a substrate that allows plants to grow and maintain [24]. According to the literature review [25, 26, 24], there are several types of green roofs with specific layering materials. Common to all of them are the same elements: roof slab-foundation, which can be made of concrete or steel, waterproofing and waterproofing membrane, indispensable protection from plant roots, drainage and/or aquifer, substrate, and vegetation.

Depending on the thickness of the substrate and the type of plants on the roof, green roofs can be characterized as intense or extensive. Intensive green roofs are mostly performed on flat roof surfaces and require a minimum of 20 cm of the substrate layer so that the plants have the same conditions as those on the ground. These plants can grow up to two meters in height, and smaller plants and lawns require regular watering. On the other hand, extensive green roofs do not require much care, because they are not exposed to active use, and belong to the lighter types of green roofs where the thickness of the substrate ranges from 7 to 12 cm. Therefore, old classic roofs can be adapted to this type of green roof [24].

Although it is a popular opinion that green roofs have an aesthetic role, they also have much more important functional roles, such as reducing the temperature, which is most important in cities, reducing the energy consumption of the building, and enabling recreation. In addition, green roofs retain up to 90% of rainwater and thus facilitate the sewage system [26]. Green roofs are also air purifiers, and further explain that one square meter of a green roof can purify 0.2 kg of smog dispersed in the air (exhaust gases, smoke, dust…), and in 1 year can absorb up to 5 kg CO_2. Green roofs can provide additional sound insulation and reduce noise by up to 10 dB. It is desirable to build them in areas of high noise, such as areas near airports, heavy industry, etc. Furthermore, they conclude that green roofs with a layer of vegetation, substrate, and non-combustible roof construction-concrete, reduce the possibility of spreading fire [27].

Green roofs can extend the life of a classic roof by almost double, looking at prices that are almost the same [23].

Green Walls and Green Facades. Besides the environmental impact, the green wall provides thermal insulation and establishes a consistent building temperature [28]. They can be completely covered with vegetation or just partially, as they can be outdoor and indoor [24].

For the successful realization of the green wall, it is necessary to consider the adequate position of the wall during the design, and the construction of the load-bearing structure, carefully observe the climatic conditions, and choose the appropriate plant material. [29]. When it comes to layers of green walls, they are very specific but also similar to the layers of all other green structures. They consist of plant material, substrates in the form of synthetic fibers or inorganics such as plastic, waterproofing system, various moisture protection membranes, irrigation systems, and load-bearing structures (to transfer green wall load to facade construction), and lighting that allows photosynthesis [25].

Traditional green facades are made with climbing plants that climb the walls. They are also known as one of the oldest methods of green walls. These species grow from the ground or from pre-designed pots, where the walls of the building serve as supports. What is specific about these facades is that the plants need a lot of time to cover the entire wall [24].

Living Walls – Modular Panels. As an architectural element, there is also a system of vertical gardens that are organized in pre-prepared and planted panels, known as modules with plant growth medium [24].

2.2 Economic Principles: Cost Efficiency

It is generally considered that green buildings are much more expensive than conventional buildings and that they are not worth the extra cost [30]. Several dozen building representatives and architects were contacted to compare the cost of 33 green buildings from across the United States with the cost of conventional designs for those same buildings when they realize that the average premium for these green buildings is 2% which is considerably lower than is usually perceived. The cost of a green building is mainly related to the increased time of architectural and engineering design, and modeling costs but also the time required to integrate sustainable construction practices into projects. A green building provides economic benefits that conventional buildings do not have, such as energy and water savings, reduced waste, improved indoor environmental quality, greater comfort/productivity, and lower operations and maintenance costs. Also, a green building consumes on average 30% less energy than conventional buildings, which he explained in the specific example: if the average annual energy price of buildings in Massachusetts is approximately \$2.00/ft^2 (approximately \$25.53/m^2) then the reduction for a 100,000 ft^2 (approximately 9290 m^2) state office building is \$60,000 per year. With a 20-year present value of expected energy savings at a real discount rate of 5% worth about three-quarters of a million dollars [30].

Very often new projects consider both green building and standard construction techniques, when the final decision is made based on budget, schedules but also long-term effects [31]. The benefits of green building design and construction on a manufacturing facility in Pennsylvania, comparing old and new manufacturing facilities. A new facility built on green building principles offers more advantages in daylight, air quality, and thermal comfort. Also, employees generally agreed with these conclusions, and they are more satisfied with their work area but also building itself. After measuring the impacts of the green building on the productivity, health and safety, absenteeism, and energy savings of mentioned facility and its employees, the decision to build a green building was correct and it is justified not only from the environmental point of view but also economic [31].

A comparative case study is made using two green-certified industrial manufacturing buildings and a similar-natured conventional building to establish the economic sustainability of green buildings in a sense of the life cycle cost. This study shows that the cost of building a green industrial production building is 37% higher than the cost of a conventional building of a similar nature, but when considering the costs of operation, maintenance, and end life of green buildings, savings of 28, 22 and 11% are seen. According to these calculations, in Sri Lanka where the study is done, the overall cost saving in green buildings is 21% [32].

Literature Review Findings. According to a literature review of 3 different studies, we can conclude that green building provides economic benefits in comparison with conventional buildings in the conservation of building or later maintenance costs such as energy and water savings, reduced waste, improved indoor environmental quality, greater comfort/productivity, and lower operations costs.

2.3 Social Principles: Design for Human Adaptation

After all the problems the world is facing caused by significant pollution and high levels of greenhouse gas emissions, an important pillar for the implementation of green building projects is the protection of human health and physical resources. The social pillar of green building includes improving the quality of life, ensuring social self-determination and cultural diversity as well as protecting and promoting human health through a healthy and safe working environment [9].

Observing the habits of modern society, more than 70% of modern man's time is spent inside. The role of architecture is to become a tool in improving the safety, health, physiological comfort, physiological satisfaction, and productivity of those who use the built space. Quality and comfort are often lost due to preoccupation with style and form. A sustainable product must work well, i.e., it must not allow negative effects on users and their productivity, while the importance of energy savings is unquestionable in the case of a sustainable project [10].

A sustainable industry must balance human needs with the available natural and cultural environment. This further leads to the construction of a healthy building, which does not contain hazardous materials and directly promotes health and comfort in the space where the entire life cycle is spent. The designer must plan healthy facilities that will meet the needs of social life but also increase human productivity. A few features that belong in green buildings to humans are thermal comfort, the acoustical environment, daylighting, natural ventilation, building functionality, and building aesthetics. But also, designers must eliminate any hazard in advance by making a plan for fire protection or crime prevention [9].

Thermal comfort is achieved through the synergy of parameters such as indoor air temperature, indoor surface temperature, indoor humidity, and airflow in the room. Today, there are regulations and legislation that state the exact numerical values calculated for preserving human health, and which refer to the mentioned parameters. To achieve visual comfort, it is necessary to balance the influence of lighting and adjust the values of the reflection index determined for rooms with different functions, and in addition, the importance of reflection coefficients of any surface cannot be ruled out because they are a secondary light source [33].

The undeniable facts that benefit public health are the inclusion of greenery, natural light, and visual and physical access to open spaces, not only in residential buildings but also in other buildings, because landscaping not only supports the environment and habitat of other species on the planet [34].

Literature Review Findings. Designing for a human means not only satisfying his physical and obvious needs but also the needs of his health and mental condition, which are nourished by many parameters from the environment of which the individual is generally unaware. This includes stimuli from the environment that affect thermal and acoustic comfort of space, visual and aesthetic satisfaction when using the space, as well as eliminating feelings of fear and physical insecurity caused by predictable or unpredictable hazards. The authors of this paper are listed in Table 2. Features of Design for Human.

Table 2. Features of design for human – literature review findings.

Design for human	Features
Physical needs *(Includes building functionality)*	*Shelter for living* *Space for working (office or similar)* *Space for relaxation and entertainment (malls, arenas, etc.)* *Space for religious needs*
Health and mental condition	*Thermal comfort* *Acoustic comfort* *Visual and aesthetic satisfaction* *Natural light and ventilation* *Inclusion greenery*
Safety needs	*Safe environment from different hazards:* *-Fire protection* *-Theft protection* *-Weather protection (rain, floods, storms…)* *-Static stability in case of an earthquake*

3 Discussion

Although in this paper the discussion of materials of green building is conducted within the framework of environmental principles, the essence is that materials can equally belong to economic principles as well, if their conservation is observed. Materials with the potential to be reused or recycled as an answer to positive environmental impact, will reduce waste but also save energy and other resources, which directly leads to the field of cost efficiency - the economic principle of green buildings. When it comes to the materials in a construction process, it is assumed that if the construction firm is responsible for the waste and if there is a possibility of making their supply chain closed, then we can expect that they will reuse those materials and remanufacture products in their own site. Also, selling secondary materials should become a practice for all investors and contractors.

Effective material management in the designing process must include terms such as 'reuse', 'recycle', or 'disposal', in order to improve the environmental impact of buildings.

Much attention among researchers has been paid to the theoretical treatment of the term green buildings, as presented in this paper. It is noticeable that less developed countries in the world consciously avoid green building because of the high costs of construction, and future researchers should expand their interest and show practical examples of economic benefits in the later use of green buildings and real opportunities and interest in green buildings in countries in development.

4 Conclusion

The need for the construction of green facilities is growing, which is shown by the devastating statistics that the construction industry makes up 40% of the total greenhouse gases [6]. The construction of the facility itself, i.e., the construction technology, requires more and more attention everywhere. We must reduce this number, to preserve our living environment and natural resources, which are decreasing every day.

Researching literature and opinions of experts became clear that the construction of green buildings requires great attention from several different aspects, and this paper presented three comprehensive principles of green: environmental, economic, and social principles. Of course, the nature of these principles is complex and by going deeper into the issue, it became clear that it is impossible to separate any of these principles from the other, i.e., that green building can be implemented only if the synergy of these principles is complete.

Nature has its own laws whose correct interpretation helps to build buildings that are energy efficient. Green building provides economic benefits in comparison with conventional buildings in the conservation of building or later maintenance costs such as energy and water savings, reduced waste, improved indoor environmental quality, greater comfort/productivity, and lower operations costs.

This paper started a discussion about the technological performances of green structures where green facades, walls, and panels are mentioned. The recommendation for the other researchers is to continue a discussion of the impact of the green building on the habitat of plants such as moss and algae on the facades considering their position, orientation, and color of the façade.

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