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BIOPHILIC DESIGN IN THE OFFICE BUILDINGS: ANALYSIS OF A PRIVATE BANK IN KOLWEZI

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November, 2024

Approval

We certify that we have read the thesis submitted by Houlda Maloba Ilunga titled **"Biophilic Design in the Office Buildings: Analysis of a Private Bank in Kolwezi"** and that in our combined opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Educational Sciences.

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Declaration

I hereby declare that all information, documents, analysis and results in this thesis have been collected and presented according to the academic rules and ethical guidelines of Institute of Graduate Studies, Near East University. I also declare that as required by these rules and conduct, I have fully cited and referenced information and data that are not original to this study.

Houlda Maloba Ilunga

19/11/2024

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Houlda Maloba Ilunga

Abstract

Biophilic Design in the Office Buildings: Analysis of a Private Bank in Kolwezi

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Man shares an innate link with other living elements with which he naturally needs to be in contact for his well-being, but with the urban development that has led to many constructions, contact has become difficult. To address this, an architectural concept was put in place to meet this need by integrating natural elements into the architectural design, whether in an abstract or concrete way. Biophilic design is a true environmental investment that allows the restitution and preservation of the ecosystem and allows the continuous connection between man and nature. Therefore, this work focuses particularly on the use of biophilic design in office buildings, as this concept makes a considerable contribution to these types of buildings by promoting physical and psychological well-being, reducing energy consumption, and increasing productivity and creativity. It therefore provides a good working environment where the well-being of the building's users and that of the environment are considered. The aim of the study is to evaluate the different possibilities that can be offered by the adaptation of biophilic design in an office building. According to research, biophilic design has 14 patterns grouped into three categories and for this work, a special emphasis was placed on the first category which is nature in space and in which three systems which are green interior spaces, green walls and green roofs, were developed. In this research, qualitative and quantitative methods were used for the collection and analysis of data based on literature reviews, building evaluation as well as the evaluation of data obtained from a questionnaire. The case study that was analyzed is a private bank located in the city of Kolwezi and according to the results found and observed, taking into account the different criteria defined in the study, it is possible to say that the biophilic level has not yet been reached but that there is a real potential for an adaptation of the design in the building.

Key Words: biophilic design, biophilic design in office building, green roofs, green walls, green interior spaces

Özet

Ofis Binalarında Biyofilik Tasarım: Kolwezi'de Özel Bir Bankanın Analizi

Houlda Maloba Ilunga

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Yüksek Lisans, Mimarlık Bölümü

Kasım, 2024, 111 Sayfa

İnsan, refahı için doğal olarak iletişim halinde olması gereken diğer canlı unsurlarla doğuştan gelen bir bağı paylaşır, ancak birçok yapılaşmaya yol açan kentsel gelişimle birlikte iletişim zorlaşmıştır. Bunu ele almak için, ister soyut ister somut bir şekilde olsun, doğal unsurları mimari tasarıma entegre ederek bu ihtiyacı karşılamak için bir mimari konsept ortaya kondu. Biyofilik tasarım, ekosistemin restorasyonuna ve korunmasına izin veren ve insan ile doğa arasındaki sürekli bağlantıya izin veren gerçek bir çevresel yatırımdır. Bu nedenle, bu çalışma özellikle ofis binalarında biyofilik tasarımın kullanımına odaklanmaktadır, çünkü bu kavram fiziksel ve psikolojik refahı teşvik ederek, enerji tüketimini azaltarak ve üretkenliği ve yaratıcılığı artırarak bu tür binalara önemli bir katkı sağlamaktadır. Bu nedenle, bina kullanıcılarının ve çevrenin refahının dikkate alındığı iyi bir çalışma ortamı sağlar. Çalışmanın amacı, bir ofis binasında biyofilik tasarımın uyarlanmasıyla sunulabilecek farklı olasılıkları değerlendirmektir. Araştırmaya göre, biyofilik tasarım üç kategoriye ayrılmış 14 desene sahiptir ve bu çalışma için ilk kategori olan mekandaki doğa üzerine özel bir vurgu yapılmıştır ve burada yeşil iç mekanlar, yeşil duvarlar ve yeşil çatılar olmak üzere üç sistem geliştirilmiştir. Bu araştırmada, literatür taramasına dayalı verilerin toplanması ve analizi, bina değerlendirmesi ve bir anketten elde edilen verilerin değerlendirilmesi için nitel ve nicel yöntemler kullanılmıştır. Analiz edilen vaka çalışması, Kolwezi şehrinde bulunan özel bir bankadır ve bulunan ve gözlemlenen sonuçlara göre, çalışmada tanımlanan farklı kriterler göz önüne alındığında, biyofilik seviyeye henüz ulaşılmadığını, ancak binadaki tasarımın uyarlanması için gerçek bir potansiyel olduğunu söylemek mümkündür.

Anahtar Kelimeler: biyofilik tasarım, ofis binasında biyofilik tasarım, yeşil çatılar, yeşil duvarlar, yeşil iç mekanlar

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DRC: Democratic Republic of Congo

UMHK: Union Miniere du Haut-Katanga

ATM: Automated Teller Machine

Cwa: Monsoon-influenced Humid Subtropical Climate

CHAPTER I

Introduction

This first chapter, which introduces the research topic and gives an overview of the study, includes the problem, the purpose of the study, the significance of the study, the limitations as well as the definitions of the terms addressed in the research.

Man has always been linked in one way or another with nature, whether with animals, plants, water or other natural elements, but with the development of cities, it has been noticed that this connection is disappearing more and more and this has consequences on humans and the environment. For some time now, the world has been confronted with certain phenomena linked to climate change and limiting the damage of this climate change is one of the most important challenges of this century knowing that in a decade particularly between the year 2011 and 2020 it there has been an increase in the average temperature of 1.09°C on the surface of the planet (Renaux, 2022). This change causes fatal consequences on the natural environment such as rising temperatures, rising sea levels, increased precipitation and flooding, and many other effects on biodiversity (Lawrence et al., 2020). Climate variation is a consequence of global warming which is caused by greenhouse gases which are formed using fossil fuels and with the development of urbanization and industrialization their use is increasing (Beckers, 2017). Indeed, urbanization and industrial development have meant that most people prefer to live in the urban area to have more opportunities, but this demographic increase implies more construction and therefore more space which has consequences on the natural environment as well as biodiversity (Rodewald et al., 2014). It is therefore important to pay attention to today's actions in different fields of activity, especially the construction sector which has a large percentage of pollution (Perivoliotis et al., 2023). Considering all these effects linked to global warming, urbanization and industrialization, measures have been put in place to curb them and try to restore a long-disturbed nature as well as the relationship between man and his natural environment. This restitution is done through the reintegration of natural elements in the urban area and more particularly in the built environment thanks to the use of biophilic design which is an architectural concept which does not only consider the consumption of energy in the building but also the well-being of users by reestablishing contact between humans and nature.

The various changes that the urban area has undergone have created a separation between people and nature. Indeed, due to the increase in buildings and other impermeable surfaces, natural areas have been largely reduced, which has put a barrier between humans and nature, which according to studies has consequences on humans and on the environment (Azzi, 2023). Man as a living entity has an innate capacity or predisposition to be attracted to other living organisms and this love for life is called biophilia. According to the etymology of biophilia, the word comes from two Greek words “bio” which means life and “Philia” which means love, biophilia is therefore the love of life (Barbiero & Berto, 2021). The fact that life is the common point of all living entities implies a certain bond of love and recognition of other creatures and nature (Barbiero, 2014). This biological affiliation of man towards the natural elements means that beyond just considering and appreciating them, man needs them whether through direct contact, indirect contact or even visual contact for his well-being. Considering the fact that people spend more time indoors than outdoors but need to be in contact with nature, a concept was put in place to bring natural elements into the built environment to allow continuous contact between people and nature. Biophilic design is an architectural design that gives city residents the opportunity to stay in continuous contact with nature because they are biological organisms. It is a concept whose mission is to maintain, through several types of integration, the link between human beings and nature (Kellert & Calabrese, 2015). According to the classification of William Browing and Jenifer Seal-Cramer, there are three categories of biophilic design which are Nature in Space, Natural Analogies and Nature of Space (Browning et al., 2014), and this work is based more on biophilic design for office buildings.

Office buildings are complex constructions which have a particular functioning. It's a place where workers spend a lot of time working and being creative. It is a place which can be for other sources of stress and many other problems, which is why they need a particular arrangement to offer users an adequate environment so that they can flourish and be more productive (Nag et al., 2019). Biophilic design is ideal for a work environment because it has an impact on cognitive abilities, it helps stimulate creativity, brings physical and mental well-being and many other benefits (Makes & Sense, 2012). Given the fact that people spend several hours of the day in offices, it is important to offer them a pleasant and, above all, ideal environment so that these times spent are not unbearable. Bringing nature into the office is an effective way to reestablish contact between office building users and other living organisms to which they are

innately connected, which makes it possible to respond not only to problems of spatial organization or functionality of workspaces but also respond to a biological need.

To do this, this study focuses on the different aspects of biophilic design and on the possibility of applying it to a particular case study which is a Private Bank in Kolwezi, in the province of Lualaba in the Democratic Republic of Congo.

Statement of the Problem

People spend a lot of hours inside buildings due to their work, usually they spend 35 hours per week and in some cases, others go up to 50 hours per week. This time they spend in the built environment enforces a separation between human beings and the natural environment. The office building is rather a particular place where a lot of activities take place throughout the day and even at night depending on the activities carried out there. These different activities mean that the building has a high energy demand, which poses a problem for the interior and exterior environment at the urban level. The workplace itself is an environment where pressure is constantly present because there are tasks to carry out and schedules to respect for most of the time and its layout has a real impact on the quality of the work of employers and on company performance.

In Kolwezi, because of the climate variations which imply considerable modifications in the temperature and the level of precipitation and the nature of its environment which is an active mining area, it is difficult to find a working environment which is really adapted to the local situation and the physiological and biological needs of those who spend many hours working there.

Purpose of the Study

This study, which focuses on biophilic design in office buildings, aims to:

- To assess the potential of adapting biophilic design in an office building in the mining town of Kolwezi to provide workers with an adequate working environment that can support user productivity and well-being.

- Evaluate the possibility of spending hours in the built environment while remaining in continuous contact with nature.
- Demonstrate the benefits and different possibilities that biophilic design offers in building design in general and in office buildings in particular as well as its contribution to people, in buildings and at the urban level.
- To raise awareness of the importance of plants indoors and outdoors and their contribution to mental and physical health as well as the environment.

Research Questions

Adapting nature into an office building in Kolwezi is a real challenge given the fact that biophilic design and all that it entails is not yet very well understood in this city. Nevertheless, for everything it is likely to provide, this architectural design is ideal for healthy workspaces that promote creativity and intellectual development.

For the development of this study, it will therefore be necessary to answer certain questions which will allow us to have more precision on the subject and thus arrive at a constructive conclusion such as:

- What is biophilic design and its importance and contribution to architectural design in general and to the design of office buildings in particular?
- What is an office building?
- How can natural elements be used in a work environment to promote the well-being of employees and the development of the company?
- Is it possible to adapt the biophilic design in all office buildings and in particular the private bank building in the mining town of Kolwezi?

Significance of the Study

Biophilic design is a design that presents several opportunities and this study on this subject helps to show an openness to the possibility of a real change in the interior environment in general and the workspace in particular. Indeed, the adaptation of biophilic design in office buildings can solve the problem of stress and concentration at work and reduce the impact of

urban development and climate change. This study shows the importance and possibility of using nature in the workspace even for a company located in a mining area.

Limitations

Biophilic design is a vast subject that should be explored in a specific manner and for this study, based on the classification of William Browning and Jenifer Seal-Cramer who subdivided biophilic design into 3 classes which are Nature in the Space, natural analogies and the Nature of Space, the research essentially focuses on the first classification which is nature in space. This work is therefore focused on nature in the office space where three systems are exploited including green interior spaces, green walls and green roofs.

Definition of Terms

Below are the definitions of the different terms discussed in the thesis.

- ***Biophilia:*** It is the innate ability of human beings to seek contact with living entities.
- ***Biophilic Design:*** It is an architectural concept that connects the users of a building with the natural elements.
- ***Office Building:*** It is a building that houses workspaces and meets the specific requirements of office work.
- ***Biophilic Design in the Office Building:*** It is the integration of natural elements in an office building
- ***Green Interior Spaces:*** These are indoor spaces that are landscaped with plants arranged in such a way as to integrate with the indoor environment.
- ***Green Walls:*** These are walls covered with plants. Depending on the type of wall chosen, there can be just a wall with climbing plants or a vertical garden.
- ***Green Roofs:*** These are roofs covered with plants in different shapes. Depending on the type of roof chosen, there may be just a roof with a few plants or a garden on the roof.

CHAPTER II

Literature Review

In this second chapter, conceptual definitions, detailed descriptions and existing data on the subject are provided. It therefore contains information on biophilic design, office buildings, biophilic design for an office building, nature in an office building, green interior spaces, green walls, green roofs as well as related research that made it possible to have the specific data on the study.

Theoretical Framework

Biophilic Design

In 1984, Edward Osborne Wilson who is an American biologist formulated a hypothesis according to which biophilia is a genetic need which consists of a connection with other forms of life and therefore to be in harmony with nature. Based on this statement, it is possible to understand that there is an innate link between human beings and other forms of life (Downton et al., 2017). Biophilia is therefore a natural inclination which pushes man to seek contact with nature for his general well-being (Kellert & Calabrese, 2015). As a result, it is a theory which attempts to determine the links between man and his environment. However, the biophilic concept is like a practical application of this theory because it is a means of sustainable design which aims to promote the reconnection between humans and nature (Downton et al., 2017).

The biophilic concept is a sustainable design method that allows architecture and the urban environment to be closer to nature and users to enjoy the view and the well-being it provides. Its aim is therefore to reconnect the uses of a building with nature through the integration of different types of natural elements (Gillis & Gatersleben, 2015). A study showed that people spend on average 90% of their time inside a building (Klepeis et al., 2001) and this time spent inside is the basis of the disconnection between man and his natural environment which is not without consequences on one's physical and mental health and well-being (Baggerly et al., 2015). This is why the great challenge of biophilic design is to re-establish people's affinity with nature because it is important to recognize that it is good for the well-being of human beings when they are in contact with it (Kellert, 2018). It is designed to fill the gaps that have caused the interior space to be the basis of the disconnection between man and his natural

environment by reducing his time of exposure to nature. For this, a new design framework is put in place for the integration of nature into the built environment to create a suitable place for people without removing them from the natural atmosphere (Kellert & Calabrese, 2015). It is therefore ecological design centered on man and nature which allows the creation of an environment favorable to their well-being (Richardson & Butler, 2022).

History of Biophilic Design

Seeing some buildings and architectural works that were constructed in past centuries, it is possible to notice that many of them were designed with the idea of integrating natural elements which is clear proof that the design biophilic has existed and been put into practice for a very long time (Browning et al., 2014). During these periods, people had contact with nature but the industrial revolution which took place between the 18th and 19th centuries brought a certain imbalance in society. Indeed, between the years 1760 and 1832 there had been noticed in England a certain number of technical inventions such as the steam engine, photography, gas lighting and many others which disrupted the criteria of performance in different fields and the transition between agricultural and industrial caused significant demographic growth in the city (Bairoch, 2017). Seeing this increase in population which also implied an increase in construction, the authorities took considerable measures to set up urban parks for the well-being of the population (Browning et al., 2014).

In 1964, the German psychologist Erich Fromm was the first to invent the word "Biophilia" and defined it as a psychological disposition to love what is alive which implies the love of living beings for nature because biophilia has a restorative power over man (Fromm, 1956). He describes biophilia as an innate need specific to men (Fromm, 1992). Biophilia is, however, conditioned by a natural evolution of environmental and social conditions because it involves the development, consideration, respect and flourishing of nature to allow harmonious cohabitation (Gunderson, 2014).

In 1984, American biologist Edward Osborne Wilson was the second to invent the word "Biophilia" defining it as an innate tendency that drives humans to attach and focus on all forms of life (Barbiero & Berto, 2021). His evolutionary point of view places particular emphasis on fascination and affiliation which refers to an emotional bond that creates empathy when contact is established between humans and nature (Hand et al., 2017). Both provided hypotheses that can

be considered between psychology and biology, the first of which was based on an ontogenetic perspective and the second on a phylogenetic perspective.

Biophilia is a human character based on biology which allows the establishment of a harmonious relationship between humans and other living entities. With modernization and the urban lifestyle, the contact of men with nature has been limited, which over time has led to a separation which has consequences on physical and mental health because according to certain studies, there is a relationship of dependence of humans on nature (Kellert & Wilson, 1993). The connection with nature depends on the value placed on it and the type of contact that it is possible to establish with it (Bratman et al., 2019). With urbanization, many people have not had the opportunity to experience regular and direct contact with nature (Chawla, 2016). This contact allows you to create a close link with the natural environment and this human experience facilitates a commitment to its conservation (Berto & Barbiero, 2017). With urban development advancing rapidly this is becoming more and more difficult because more and more people want to live in the city and according to forecasts from the World Bank, by 2050, 75% of people will move to the urban area (World Bank, 2019). To not let this development create a divide between man and his natural environment, it was necessary to learn and intentionally change the way of designing urban spaces (Barbiero & Berto, 2021). The new way of designing makes it possible to create an environment where natural elements are integrated into the built environment to promote biophilia (Hartig and Kahn, 2019). This integration presents many advantages such as increasing productivity in workspaces (Browning & Romm, 1994), accelerating the healing process through contact with nature (Ulrich, 1984), reducing stress, improvement of intellectual performance, social interaction (Browning et al., 2014). The link with nature is important and evolving, it is therefore important to create an environment, although artificial, which ensures the continuity of this contact so that nature can act in a beneficial way on people (Soderlund, 2019). Through biophilic design, it is possible to stay in touch even in cities (Kellert, 2008).

In the 1990s, a study made it possible to definitively determine the contribution that biophilic design has on productivity (Heerwagen and Hase, 2001). In 2004, a conference was organized on the passage of biophilia as a basis for architectural design and following this a study on biophilic design was published in which mechanisms of biophilic experiences were identified as well as three classifications of design biophilic which are Nature in space, the

Analogy of nature and the Nature of space (Kellert et al., 2008). Since these discoveries, several studies focusing on the links between architecture, biology and psychology have been made and several construction standards have been readjusted in order to allow the integration of biophilic design which is an architectural design which takes into consideration the fact that users of built environments are biological mites (Browning et al., 2014). Biophilic design uses natural elements in the building to stimulate human beings, which has an impact on their different capacities and performances because the ideal living or working environment promotes intellectual development (Abdelaal & Soebarto, 2018).

Benefits of Biophilic Design

Bringing nature into a building has many benefits on physical and mental health by reducing stress, promoting productivity, developing intellectual abilities and improving cognitive performance (Aristizabal et al., 2021). It is also important to note that the connection between building users and nature not only has benefits for humans but also for the environment (Wijesooriya & Brambilla, 2021). The concept also promotes a certain repair of biodiversity (Richardson & Butler, 2022) and the mitigation of the considerable impact that construction has on the environment as well as the reduction of energy consumption (Wijesooriya & Brambilla, 2021).

Biophilic design is a concept which, through its application, aims to provide several benefits, notably:

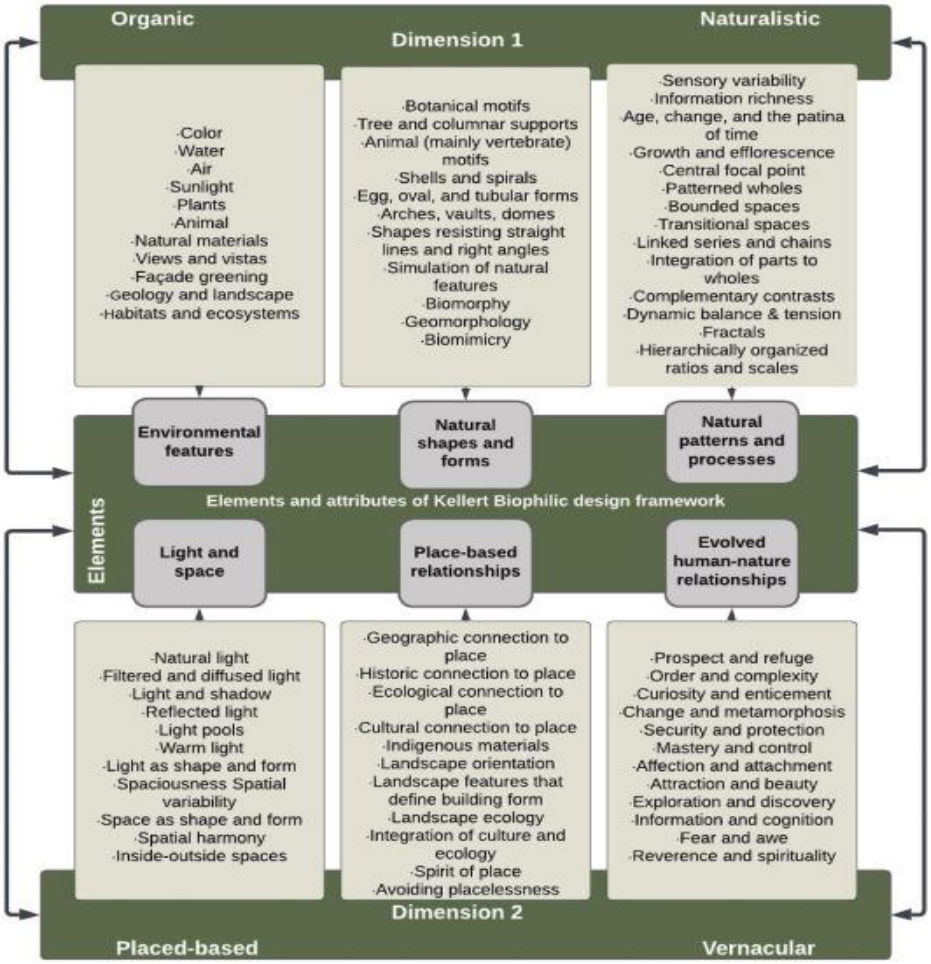
- Permanent engagement with nature to promote affection for the environment and specific places (Richardson & Butler, 2022)
- The adaptation of human beings to nature
- Promoting interaction between people and nature
- Development of a sense of responsibility towards the natural environment
- Encouraging the architectural integration of reconnection elements
- Maintenance of the functioning of the natural system. (Kellert & Calabrese, 2015)
- Supporting the well-being of humans and nature (Richardson & Butler, 2022).

The Principles of Biophilic Design

Biophilic design is a strategy that allows the integration of nature or even the reminder of nature in the built environment and for it to be integrated correctly there are principles that serve as fundamental bases for good practice of the concept (Wijesooriya et al., 2023). The connection to nature can be direct through the presence of natural elements in the building or indirect through elements referring to nature and according to Kellert (2008), biophilic design can be perceived in two dimensions and it can therefore be either natural or organic and from these two dimensions emerge six elements or design principles with 70 attributes (Figure 1) (Hassankhouei1 & Mojtabavi, 2023).

Figure 1.

The Dimensions of Biophilic Design and their Attributes



(Wijesooriya et al., 2023)

The Patterns of Biophilic Design

Biophilic design is an important concept adopted by architects, decorators and landscapers in carrying out projects because it allows building users to reduce stress, improve well-being, productivity and accelerate healing. This concept offers a healthy and adequate environment depending on the chosen design. It is therefore characterized by the presence of nature in space, which allows a visual connection with it and a physical connection with it (Franco et al., 2017). For several years, in-depth research has been carried out to provide a solid basis which allows a detailed design of different projects and 14 biophilic design patterns have been established (Browning et al., 2014). They can be applied in a diverse manner both indoors and outdoors and can easily adapt to the type of project, location and users. Biophilic design is done in a flexible manner and turned towards nature to allow restoration of the environment without disrupting the spatial organization of the place (Ryan et al., 2014). However, the patterns remain just guides which support the design process and the type of model to be put into practice depends on the nature of the project according to the needs of the users so that at the end of the construction, a building promoting reconnection between humans and nature can emerge (Radha, 2022). To give more precision on the 14 patterns, they have been grouped into three categories which are “Nature in space”, “Natural analogues” and “Nature of the space” (Table 1 and Figure 2) (Browning et al., 2014).

Table 1.

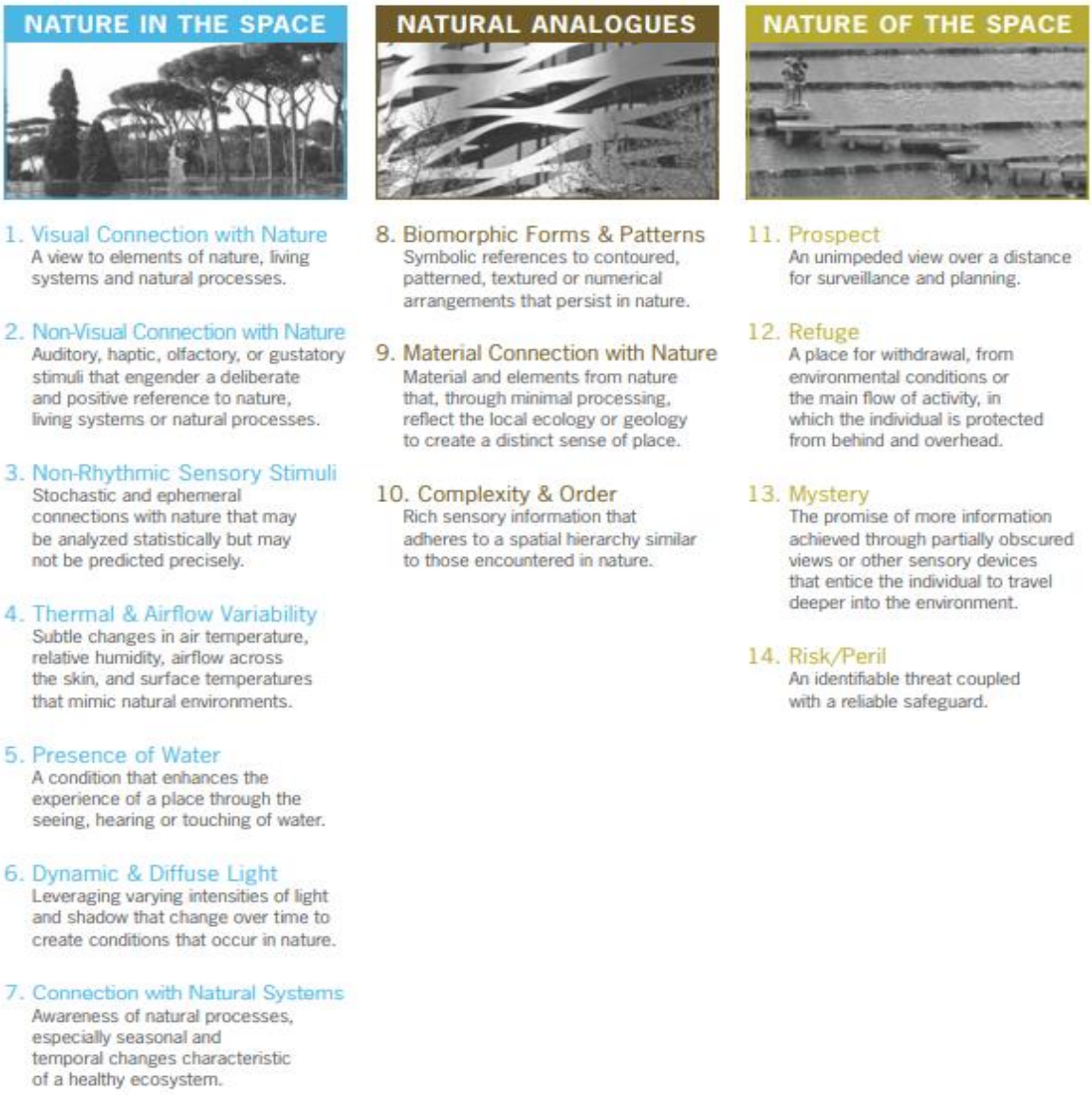
Biophilic Design Patterns and their Categories

Biophilic design patterns	
Nature in space	1. Visual Connection with Nature
	2. Non-Visual Connection with Nature
	3. Non-Rhythmic Sensory Stimuli
	4. Thermal & Airflow Variability
	5. Presence of Water
	6. Dynamic & Diffuse Light
	7. Connection with Natural Systems
Natural analogues	1. Biomorphic Forms & Patterns

	2. Material Connection with Nature
	3. Complexity & Order
Nature of the space	1. Prospect
	2. Refuge
	3. Mystery
	4. Risk/Peril

Figure 2.

14 Patterns of Biophilic Design



(Terrapin, 2014)

Nature in Space: Nature in space refers to the presence and direct contact with nature in the built environment. This nature includes elements such as flowerpots, plants, aquariums, bird feeders, water features, green walls and green roofs (Browning et al., 2014). The goal of nature in the built environment is to re-establish the relationship between the urban area and the natural environment and thus humans and nature and also to realize the potential that nature can have on the city and its inhabitants (Totaforti, 2020). Its presence is important to allow people to be emotionally attached to the place, which often implies a commitment on their part to the preservation of nature (Ryan & Browning, 2020). The concept promotes the creation of a place characterized by environmental quality (Wijesooriya et al., 2023). Nature in space is therefore defined as the presence of several types of natural elements in the building such as water, plants, natural light, animals and this contact has the same effect as being in a natural setting outside (Radha, 2022). This category is therefore the simplest and most effective because it allows you to be directly in contact with nature (Figure 3) and allows you to create a biophilic design from simple elements such as potted plants, an aquarium, a green wall or even a green roof which can serve as a place to relax.

Figure 3.

Nature in the Space, Bank Pekao, Poland

(hbreavis, 2022)

Natural Analogues: Natural analogues refer to biological evocations which are not living, and which are not directly linked to nature such as colors, materials, works of art, textiles, etc. (Figure 4) (Browning et al., 2014). These are artificial elements that recall nature such as the use of organic forms for the manufacture of furniture, decorative objects such as works of art or even for the design of buildings (Ryan et al., 2014). It is any element, pattern or even painting that reflects nature in one sense or another in order to extend the link with true nature (Larsson & Krishnaraj, 2023).

Figure 4.

Natural Analogues according to the 14 Patterns of Biophilic Design

(Browning et al., 2014)

Nature of the Space: The nature of space refers to a spatial organization which allows us to push the imagination beyond the visible environment (Figure 5) (Browning et al., 2014). This category refers to the feeling aroused by an architectural design or a spatial organization, a view of natural elements or one reminiscent of nature and the fact that a place gives the impression of being linked to nature (Larsson & Krishnaraj, 2023). Unlike the other two classes which represent the physical aspect of nature, this third dimension has a psychological character (Ryan et al., 2014).

Figure 5.

Nature of the Space according to the 14 Patterns of Biophilic Design

(Browning et al., 2014)

Office Building

An office building is a building that generally houses workspaces. The building can be occupied by a single company or by several depending on its size and its operation and in this case, it has common spaces that all companies can use and specific spaces for each (Haoui, 2015). It is a place where several activities take place throughout the day and sometimes even at night, which implies that the quality of the building is important and must meet certain standards of design and functionality to allow good working conditions (Larceneux, 2017). Indeed, certain aspects such as the quality of the area, the acoustics, the ambient temperature or even the quality of the light have a great effect on the creativity and productivity of workers. Therefore, it is important to consider the design because the quality of the building and its environmental impact influence the quality of life at work (Andriot & Larceneux, 2022).

Initially, office buildings were installed in several ways provided that work could be carried out there but currently due to certain constraints several have adapted to the new standards (Nag et al., 2019). They are often designed in a more technical, functional approach, taking account of location and accessibility (Butin, 2023). Office buildings have brought a plus in architectural design through technique, operation and layout and this is developing constantly because they are buildings whose space is considered evolving (Rey, 2004).

Another important aspect to consider in an office building is energy consumption, which is considerable these days. It is therefore more advantageous to build according to the climate to reduce energy consumption thanks to a judicious choice of construction materials (Bano & Kamal, 2016). Indeed, given the number of hours that buildings are occupied, depending on the climate, there is often excessive use of air conditioning or heating depending on the climate, but thanks to suitable materials, it is possible to reduce this energy consumption. Another aspect to consider is the use of daylight because appropriate light promotes the well-being of workers and saves energy (Rastegari et al., 2021).

Building Function

An office building is a place where different professional activities are carried out and is therefore configured in a particular way to ensure its proper functioning. Depending on the architectural design, it can be directly built with different spaces, or it can just as easily be just a free plan which will then be partitioned as needed (Tan et al., 2024). There are several types of office buildings that can be used as banks, administrative institutions, coworking spaces or even companies that offer several services (Grzegorzewska & Kirschke, 2021). Offices generally have a reception, storage spaces, desks, toilets, a cafeteria, a conference room etc. Beyond the different spaces that make up the offices, there are also elements that are often used inside and which are also important for the functioning of the office (Figure 6).

Figure 6.

Products in the Office

Classification	Products in Office Environments
Electronics in office work	Computer, mouse, mobile phone, keyboard, headphones, plugboard, printer, etc.
Office appliances for environment	Humidifier, water dispenser, electric fan, vacuum cleaner, etc.
Office furniture	Desk, office chair, filing cabinet, etc.
Document supplies	Folder, report clip, bill clip, business card case, etc.
Record supplies	Stapler, scissors, pen holder/pen case, calendar, correction tape, pencil refill, etc.
Other supplies.	Cups, coasters, masks, disinfection supplies, etc.

(Gao et al., 2023)

Design in the Office

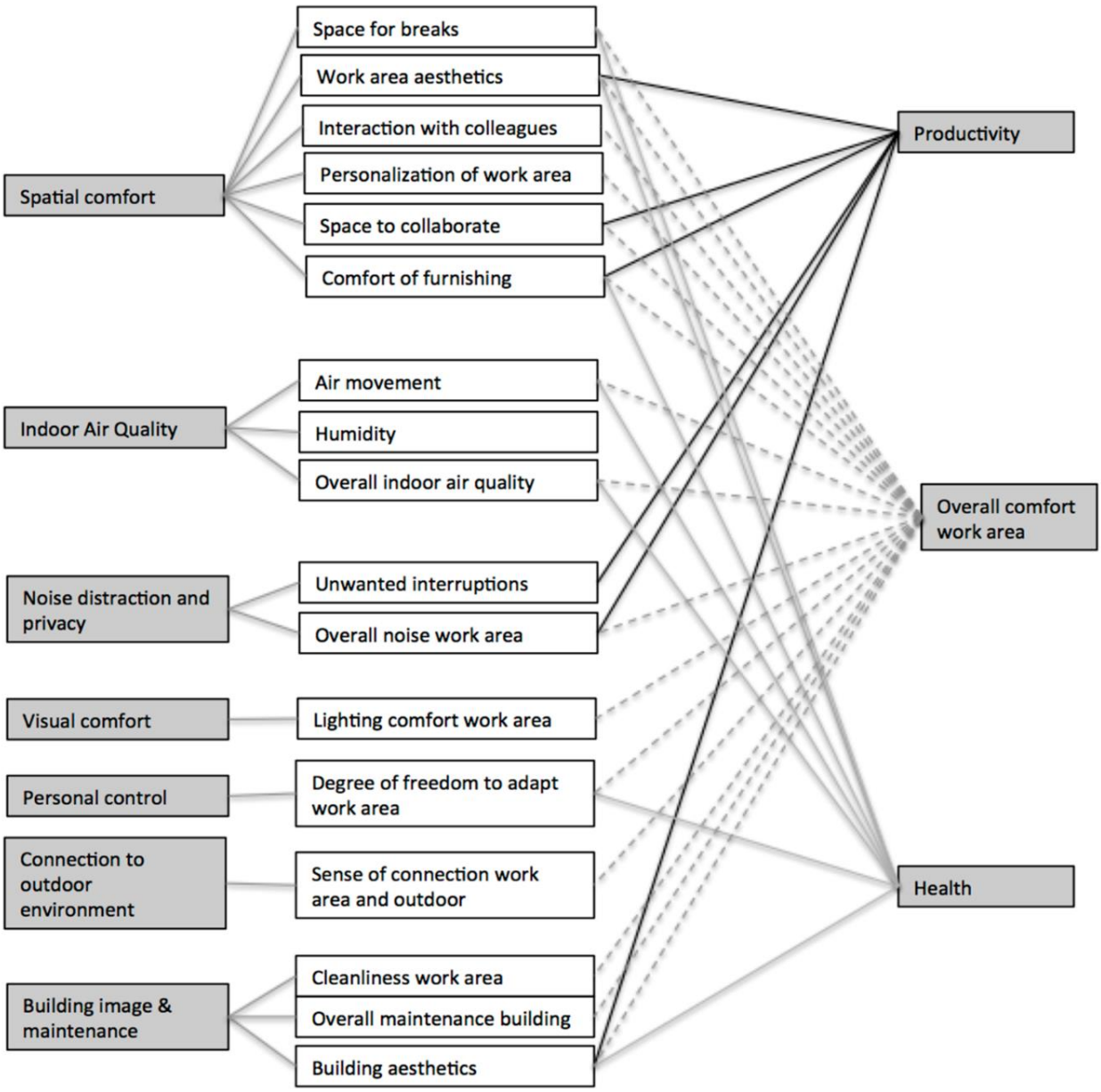
The design of an office represents the sets of decorative and functional elements that make up a workspace. This design can start from the layout of workstations to the choice of colors and lighting. The organization of a workspace is complex because it makes it possible to create spaces where all workers can adapt, and which can promote their connectivity (Van Meel & Vos, 2001). It is a process that creates an environment likely to promote the performance and productivity of employees when their safety and well-being are considered. Indeed, to opt for a healthy environment that promotes creativity, it is important to consider certain factors such as air quality, lighting, colors, ergonomics, etc. Because the perception of the working environment has an impact on the quality of work (Bodin Danielsson & Theorell, 2019).

Design is therefore important because it makes the workspace attractive and the work more efficient because the more the worker feels good in his environment, the more his productivity increases and the mood in the office is better (Van Meel & Vos, 2001). It is therefore advantageous to design an office space with the human aspect in mind because the value of a company is not only found in economic development but also in improving the working conditions of employees (CABE, 2005). It is with this in mind that considering spatial comfort, maintenance, visual perception, ventilation, noise pollution as well as the maintenance

of the connection between the interior and the exterior is important because it allows determine the satisfaction of users of the premises in relation to their perception, their health and their comfort (Figure 7) (Candido et al., 2019).

Figure 7.

Organization of the Work Space



(Candido et al., 2019)

Biophilic Design for Office Buildings

The development of urbanization and different types of construction has brought a certain gap in the environment by causing a reduction in nature and also a break between it and humans. This rupture is not without consequences on the well-being of men and their performance at work because nature has a considerable contribution to the workplace (Hähn et al., 2021). It is in this perspective that biophilic design is adopted today in office buildings because it aims to reconnect the users of a building with the natural environment to allow a direct experience, which can have a lot of benefits. Indeed, biophilic design in a workplace can improve cognitive performance, reduce stress and increase productivity (Aristizabal et al., 2021). The degree of creativity of employees also depends on the environment in which they work, which is why it is important to offer them a favorable environment and biophilic design takes into consideration physical and psychological health as well as their preferences to offer them a framework that corresponds to them. The concept came to redefine workspaces to improve certain aspects of these places and provide something even more for the future (Gao et al., 2023).

According to some studies have shown that human beings experience a natural psychological need to be in physical or even visual contact with nature and especially those who spend days working because the sight of daylight or contact with it can significantly improve well-being, morale and intellectual performance (Sanchez et al., 2018). This is why most employers prefer workplaces that give them the opportunity to be in physical or even visual contact with the elements of nature (Hähn et al., 2021). The integration of biophilic design into a workplace is therefore an important and effective strategy that allows an increase in worker performance as well as their satisfaction (Gray & Birrell, 2014). Biophilic design is therefore a concept which has a considerable contribution to office buildings and allows them to improve their manner of function. Therefore, for the concept to achieve its objectives effectively, it is important to choose a design that adapts to the type and nature of the office (Gao et al., 2023).

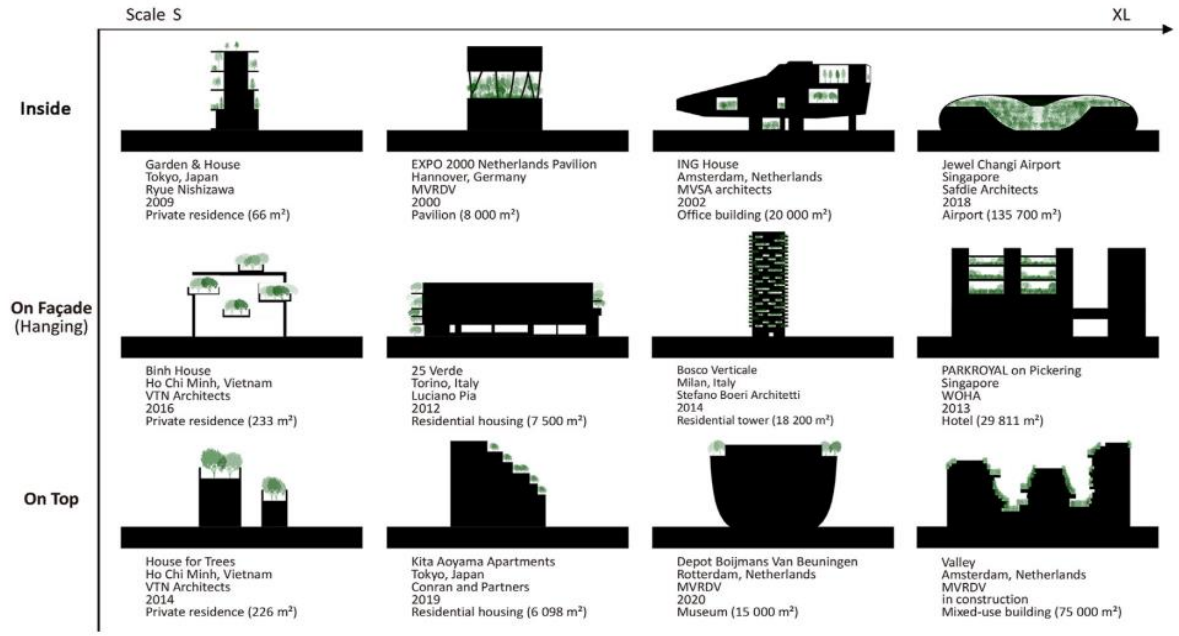
Nature in the Office Building

For some time now, the construction standards for office buildings have changed and focused on the well-being of users because it has been noted that many users develop problems linked to health and well-being (Tan et al., 2024). The design of biophilic offices has led to a

new trend that brings human well-being to the forefront even in the workspace because the introduction of nature into the office presents several advantages for workers and for performance. The presence of nature brings flexibility in the functioning of the place and this nature can be the presence of a green wall, a water point, direct access with natural light, the presence of plants or green space on the roof of the office building (Office Principles, 2024). Nature in a workspace is a strategy that helps improve the quality of life of workers and the quality of their work (Mahmoud, 2022). Biophilic design improves cognitive performance, reduces the degree of stress at work, increases the degree of concentration and creativity (Aristizabal et al., 2021). Nature in general is very beneficial for humans and particularly plants, which have a considerable impact on the workplace because they act on well-being and productivity, which allows another level of reflection to be unlocked (Nouri, 2022). Their presence influences moods, air quality by reducing indoor pollution and specifically for offices where plants can reduce the concentration of volatile organic compounds that are produced by office materials such as furniture, computers, photocopiers (Gray & Birrell, 2014). The most important characteristic of plants is that they can produce oxygen and absorb carbon dioxide through photosynthesis (Farineau & Morot-Gaudry, 2006). Today thanks to the concept of biophilic design, it is possible to create green spaces in buildings in general and in office buildings in particular which can be of several shapes and varieties (Zhong et al., 2023). For this study, three forms of green systems were used, including those inside the building or green interior spaces, those on building facades or green walls, and those above buildings or green roofs (Figure 8).

Figure 8.

Green Spaces in Buildings



(Zhong et al., 2023)

Green interior spaces

Over time, it has been noted that many of the materials used in building construction, finishes and decoration are often not ecological because they do not respect the standards of environmental preservation (Li, 2020). This implies that even the interior design of a building has a considerable impact on the environment (Wu et al., 2019). Following this observation, several people have adopted green decoration to improve the quality of the indoor environment and the microclimate (Jayasree & Kalaiselvi, 2019). Plants are increasingly used in interior spaces not only because they add aesthetic value to the place but also because they provide psychological well-being and increase the quality of the environment indoors (Shahhoseini et al., 2023).

Office buildings are rather unique places where people spend many hours working and moving back and forth throughout the day. It is a place where some flourish and for others a place of constant stress. So, to overcome this, several methods have been implemented, particularly in the design of the different buildings to offer each use a certain satisfaction.

Among these solutions is the integration of plants into the workspace because they have the virtue of soothing and contributing to the physical and mental well-being of those who are in contact with them.

Plants are important elements for the exterior environment as well as the interior because they have several virtues, one of the most important of which is improving air quality while providing oxygen. Inside they play a decorative and sanitary role (Aristizabal et al., 2021). Over time, many people have understood the importance of plants not only outside but also inside and especially in the workplace because people spend a lot of time in offices between work, meetings, appointments, some work overtime and others even work weekends. All these efforts can lead to overwork and health problems (Halim et al., 2021). This is why the office must be a healthy working environment for employees and it has been proven that those who work in an area with plants or where there are windows that overlook a green space have a better quality of life and job satisfaction (Dravigne et al., 2008). Plants therefore have the capacity to make an office healthier, which implies the possibility of physical, mental and social well-being for users (Colenberg et al., 2020). Indeed, a layout made up of plants can make a big difference in the quality of life and work of employees because they affect air quality, mood, concentration, productivity, performance and many other things (Nieuwenhuis et al., 2014). It is with this in mind that many users want to work in ecological buildings with a green interior (Figure 9) (Oyewole & Komolafe, 2018).

Benefits of Green interior spaces

For several years now, people have decided to create green interior spaces by integrating nature inside the building because this practice presents considerable advantages. Indeed, the presence of plants indoors has the following benefits:

- Optimizing the quality of the indoor environment
- Allow people to understand the importance of plants
- Allows the increase of energy efficiency in the building
- To improve indoor air quality
- To reduce the ambient temperature
- To reestablish contact with the natural environment even while being indoors

- To improve the physical, mental and emotional well-being of people
- To beautify the places where they are placed and make it more welcoming and convivial
- Oxygen production and CO2 absorption
- Improve the quality of life

Type of Green interior spaces

The type of green interior spaces is not specifically determined because there are several ways to compose a green interior which can be just by the presence of a green wall or even plant pots disposed in several ways depending on the interior decoration of the House. In office spaces the type depends on the different employees and their workspaces (Shahhoseini et al., 2023).

Components of Interior Spaces

Green interior spaces are places that have been designed to integrate nature into the interior environment and are composed of several varieties of plants and flowers that are specifically chosen according to the type of interior. Plants can be arranged in several ways such as in pots on the ground, on shelves, suspended above or even on the wall forming a green wall. There are therefore several possibilities for integrating and arranging plants inside which allow you to create the desired atmosphere.

Benefits of Green interior spaces for Offices

Beyond all the advantages that green interior spaces can bring to any interior, they are particularly important in a workspace. Indeed, the presence of plants in an office plays an important role in:

- Productivity, creativity and intellectual development by providing an environment that promotes concentration
- Reduction of stress level
- The creation of a healthy workspace that promotes socialization between different workers
- Creating a healthier working environment
- Temperature regulation which has economic advantages
- The aesthetic quality of the place

Figure 9.

Example of Office Building with Green Interior Spaces, Citibank in Singapore

A. *The interior panorama*

B. *The similarity between the inside and the outside*

(Design Anthology, 2021)

Green Walls

Today, the earth is facing environmental degradation due to climate change caused by too rapid development of the city and by overconsumption of natural resources. To remedy this gap, for several years research was carried out to find out how to reduce the impact of this degradation and green technologies, notably the green wall system, were found to be a sustainable strategy capable of participating in urban restoration (Palermo & Turco, 2020). Indeed, green walls are efficient outcomes that have considerable development potential capable of effectively compensating for the losses that the environment has suffered (Addo-Bankas et al., 2021). Due to the development of society, there is a continuous demand for energy and the green wall as an architectural element with low environmental impact (Palermo & Turco, 2020) can reduce the energy consumption of a building and thus promotes creation of sustainable cities (Maier, 2022). It is essential to consider the green wall system as one of the important elements of long-term design because it is a solution that not only respects the environment but also helps mitigate the climate impact (Ascione et al., 2020). It is considered a natural tool which makes it possible to reduce the effects of climate change and to resolve the problems encountered in the urban area (Oquendo-Di Cosola et al., 2022). Green walls are used in the treatment of gray water thanks to different compounds which can be contained in the substrate in order to make the water

reusable (Lakho et al., 2021). They are also used in the reduction of pollution firstly inside the building because during construction and development, there are different chemical products which are used, and which can be dangerous for the users of the building and the presence of a green wall indoors can improve air quality (Shushunova et al., 2023). And secondly, pollution outside the building, particularly atmospheric pollution, because plants have the ability to absorb particles through their stems and leaves, which significantly reduces the concentration of pollutants and improves urban air quality (Srbinovska et al., 2021). Green walls are important in mitigating the impacts of transportation infrastructure which is very important for the city due to its rapid development (Iligan & Irga, 2021). And they are also used in the thermal insulation of buildings (Dede et al., 2021).

The green wall system has existed since the 20th century, but its use has changed in dimension because it has gone from the simple request to just have a beautiful wall which improves the aesthetic quality of a place to a system capable of meeting the needs environmental issues on an urban scale (Addo-Bankas et al., 2021). Thanks to advances in science, green walls that have existed for a long time have evolved considerably over time to become green infrastructure playing an important role in urban sustainability (Shushunova et al., 2023). Over time, it has been observed that the more the city develops, the more the pollution rate increases (Shushunova et al., 2023), and green walls offer a functional solution that allows a certain balance to be maintained despite the increase in construction (Palermo & Turco, 2020). Despite its many advantages, the green wall system is limited and not accessible to everyone because of the cost of its installation and maintenance (Maier, 2022).

A green wall designates the different shapes of walls covered by plants. It is therefore a sustainable strategy which aims to revegetate a building for aesthetic reasons and for the rehabilitation of the urban environment to reduce the energy impact of the building and also to ensure its sustainability (Manso & Castro-Gomes, 2015). It is a system which allows the integration of nature without requiring space, but it has a great impact because the vegetation can occupy an entire facade and contributes to the durability of the building (Figure 13) (Addo-Bankas et al., 2021). Green walls play a role in the heat exchange of the building and its energy consumption. They are also effective between seasons, that is to say in summer they provide

shade and cool the air and in winter they play the role of insulation (Manso & Castro-Gomes, 2015).

Benefits of Green Walls

The green wall system is an important green infrastructure which, through its many benefits, contributes to the achievement of sustainable development objectives (Shushunova et al., 2023). It has environmental, social and economic benefits (Liberalesso et al., 2020). Green walls contribute to the enhancement of the ecosystem by participating in the development of urban biodiversity (Collins et al., 2017). These green infrastructures also have the capacity to reduce air pollution which is the basis of health problems and thus make the environment more viable (Ysebaert et al., 2021). Thus, among the benefits of adapting green walls, whether indoors or outdoors, there are:

- Improving air quality through the absorption of particles and volatile substances
- Improving the quality of life in the urban area
- Restoring contact with nature
- Reduction of temperature, reducing the impact of solar rays
- Mitigating heat islands in urban areas
- Creating a framework conducive to psychological well-being and therapy
- Increasing the performance of green buildings
- Water and air purification
- The treatment and recycling of wastewater and more often implemented to make gray water reusable
- Rainwater management
- Improving the aesthetic quality of a place and improving the urban landscape
- Noise reduction by managing sound waves
- Reducing the consumption cost of the building thanks to energy efficiency and water recycling
- Reduction in maintenance expenses because green walls protect the building from bad weather and help conserve facade materials
- Reducing the impact of buildings on the environment

- Improving interior comfort by reducing the tempering of the wall in summer and heat loss in winter
- Oxygen production and CO2 absorption
- The increase in the value of a property

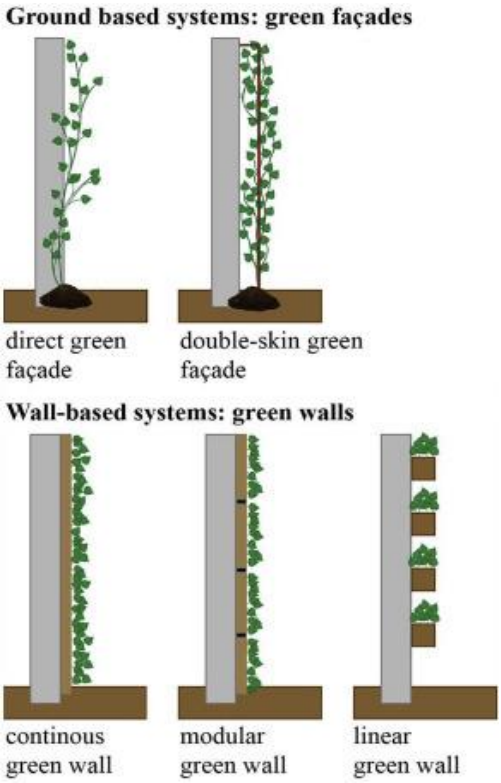
Type of Green Walls

The green wall is an element that is adopted for aesthetic, ecological and many other reasons. It can be used both indoors and outdoors and can be installed in several forms depending on the type of wall chosen as well as the type of vegetation desired. There are mainly two types of green walls which are green facades which can be applied directly or indirectly and living walls which can be continuous, modular or linear.

- **Green facades:** The first type of green walls, which are green facades, is made up of creeping plants (Figure 10). It is often called traditional type because it does not need many elements to be made and has two systems which are the direct system where the plants climb and develop directly on the wall and the indirect system where it is possible to use a wooden or stainless-steel trellis or even cabling to support the plants (Figure 10 and Figure 11). For this type of green walls, cultivation is done directly on the ground at the foot of the building or in containers (Ascione et al., 2020).
- **Living walls:** The second type of green walls, which is the living walls, is characterized by vegetation, which is directly planted on the wall, it does not require climbing plants and can therefore accommodate a variety of plants. It generally has two systems which are the continuous system where the plants are placed along the wall without interruption and the modular system where it has an interruption and where the trays which contain the plants can take other forms (Ascione et al., 2020). This type of green wall is rather autonomous, and it can be easily adapted indoors as well as outdoors because its structural support is directly glued to the wall and the support of the plants (Figure 10 and Figure 11), and their nutrients come from the inside of the support (Radić et al., 2019).

Figure 10.

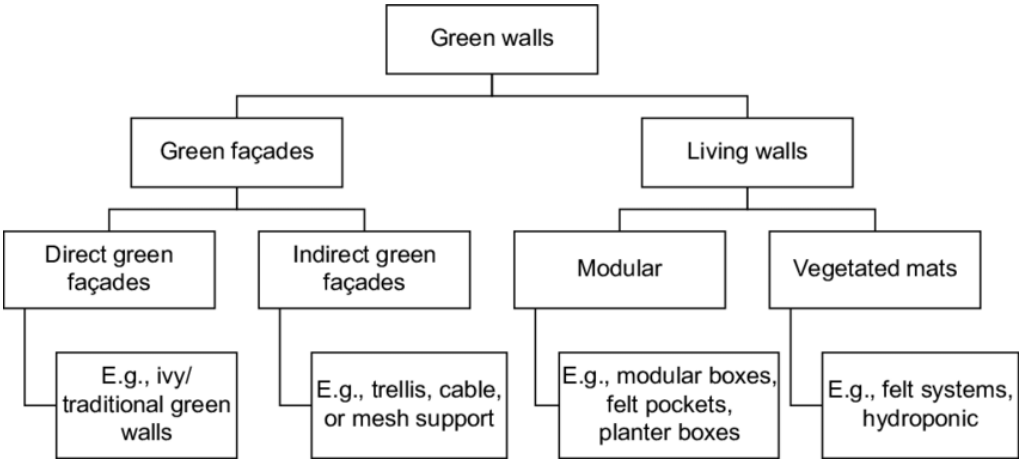
Type of Green Walls



(Medl et al., 2017)

Figure 11.

Organization of Green Walls Types



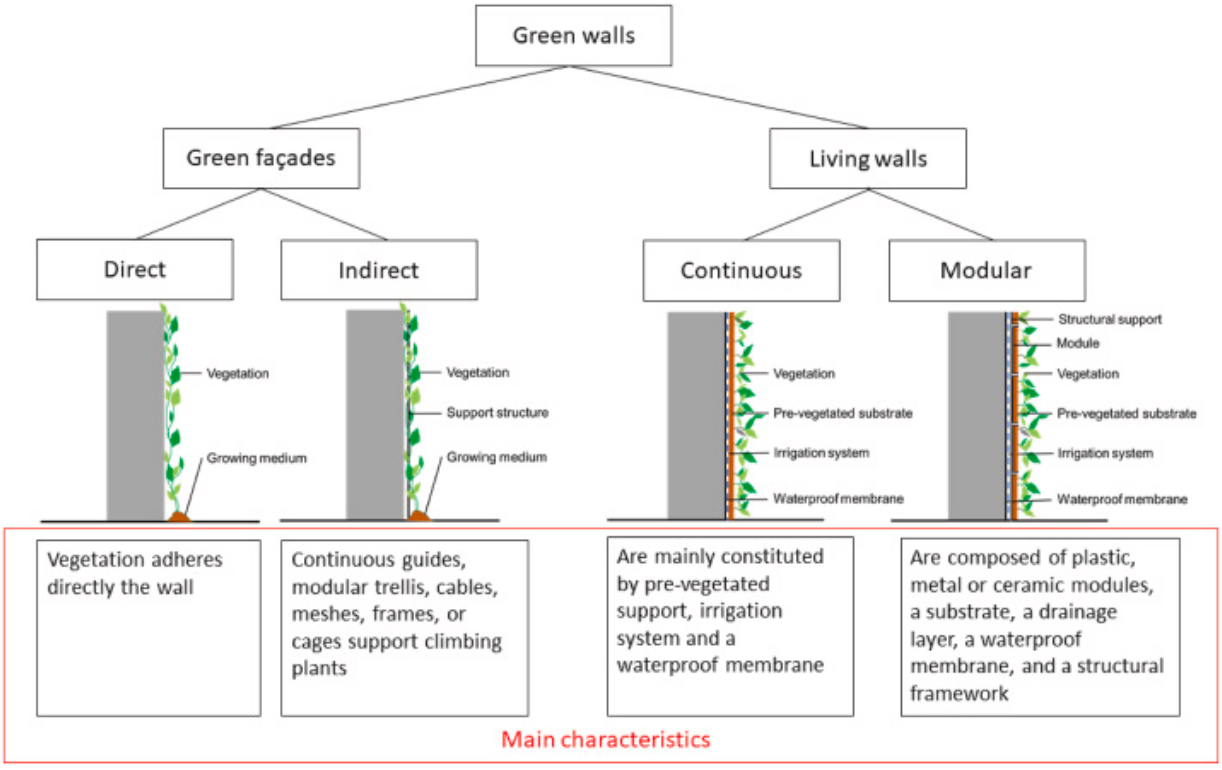
(Beecham et al., 2019)

Components of Green Walls

Green walls do not all have the same composition because it depends on the type of wall chosen. For the first type, the direct system is just composed of the soil or the growing medium and the vegetation and the indirect system is composed of the growing medium, the structural support and the vegetation. For the second type of green walls, the continuous system is composed of the waterproof membrane, the irrigation system, the pre-vegetated substrate and the vegetation and the modular system is composed of the structural support, the module, the waterproof membrane, the irrigation system, the pre-vegetated substrate and the vegetation (Figure 12).

Figure 12**.**

Components of Green walls



(Susca et al., 2022)

Benefits of Green Wall for Offices

Because of all the activities it contains, the office building is a place where the presence of plants is a real asset for workers and for the environment and the green wall in particular presents obvious advantages due to the fact that it can be adapted to the interior as well as the exterior of the building and can occupy large areas. Therefore, adopting a green wall in an office space has the following advantages:

- Improving the working environment by providing an environment that has good air quality and effective ventilation
- Reduction of noise diffusion as well as insulation of sound waves, which will allow efficient work without sound interference from outside
- Reducing the energy consumption of the building and its carbon footprint
- Thermal management of the building between summer and winter while reducing solar radiation, which allows companies to reduce the use of air conditioning and heating
- Brings aesthetic beauty to the work environment
- Allows the company to save money due to the excessive use of air conditioning and heating

Figure 13.

Example of Office Buildings with Green Walls, the Bangkok Bank Interior Green Wall

A. *Integration of the wall into the workspace*

B. *The detail of the wall*

(Fleishmann, 2010)

Green Roofs

Green roofs are systems that are considered today as an element of green infrastructure (Göç Yener, 2021). Yet their practice began well before the beginning of our era, it is just that today there is a more advanced understanding of its use and more information available on their importance. Indeed, according to certain research, green roofs have existed for several centuries, and they were used for several functions (Magill et al., 2011) and among those listed, there are those from the time of Babylon and the Roman Empire which had the habit of planting trees on the roofs of buildings (Li & Yeung, 2014). Today there is little material proof of their existence during these periods but nevertheless it is possible to find certain remains such as the Ziggurats of ancient Mesopotamia built in the fourth millennium BC (Figure 14), and which is one of the first green roof (Magill et al., 2011).

Figure 14.

The Ziggurats of ancient Mesopotamia

(Bhatt, 2018)

Since then, green roofs have continued to evolve and from the 17th century until the 20th centuries, Norway, Germany, the Americans and Great Britain used green roofs as insulation, as a palliative for wood, to reduce the fire risk and as camouflage for hiding military airfields and in 1931, the Rockefeller Center in New York (Figure 15) which is considered the first modern green roof given its importance was built (Magill et al., 2011).

Figure 15.

The Rockefeller Center in New York

(Rockefeller Group, 2024)

It was from the 20th century that several countries adopted green roofs and several research projects were carried out to correctly develop this technique. Among the first countries to research and adopt green roofs was Germany, which in 1996 already had 10 million square meters of green roofs, which allowed other countries to take an example (Peck et al., 1999). From this period, plans were drawn up to allow the implementation and maintenance of green roofs which have become essential thanks to their ability to manage rainwater and solar energy (Getter & Rowe, 2006). Indeed, understanding the issues and impact of urbanization on the environment and society, the green roof presented itself as one of the solutions to mitigating the effects of climate change.

Urbanization has meant that more and more people want to live in the urban area, which has involved the construction of many high-rise buildings and the more it develops the more it leads to a reduction in natural areas (Manso et al., 2021). This rapid sprawl of cities and the misuse of significant natural resources have a real impact on the environment and society

(Teotónio et al., 2021). The construction sector by the space and different materials used in the construction of buildings is responsible for 40% of energy consumption (Perivoliotis et al., 2023). This is a large percentage which presents consequences on the environment which must be reduced in order to achieve a certain urban sustainability and also allow the climate to be less disturbed. To achieve urban sustainability, it is important to overcome the densification of cities and their consequences (Manso et al., 2021) and for this it is necessary to make restitution by restoring certain green infrastructures which have diminished due to the urbanization which has made them transform into roads and buildings (Göç Yener, 2021). The absence of green spaces has also allowed people to really realize their importance on the well-being of people, on the environment and on the regulation of the climate (Hoeben & Posch, 2021). Indeed, green infrastructure and more particularly green roofs offer the possibility of regenerating and renovating the urban area because they are ecosystem solutions that can greatly improve its performance (Teotónio et al., 2021). Many people have invested in the installation of green roofs because they offer the opportunity to be close to nature and this has led to another style of construction (Kader et al., 2022). It is a natural system that was put in place to mitigate air pollution, reduce the building's energy consumption and improve conditions in the building (Perivoliotis et al., 2023). Given the fact that urbanization is developing rapidly, there are areas that are very populated and, in this case, it is easier to install a green roof due to the lack of space (Shafique et al., 2018). This means that even in these areas it is possible to enjoy the benefits of green roofs to allow the absorption of pollutants, the management of temperation and the protection of fauna (Teotónio et al., 2021). Despite the different benefits that green roofs offer, they cannot be practical everywhere because their installation has a cost. However, its real value in relation to environmental and social benefits strikes a certain balance (Teotónio et al., 2021).

The practice of green roofing has existed for a very long time and is adopted for several reasons which can be aesthetic, ecological or even spatial. It is an arrangement of several materials and plants on a building, very often with a flat roof or a low slope (Figure 18). For several years now, light has been shed on the use of green roofing and this has led to its development because it is a practice which allows the connection between an artificial structure and nature not only for reasons of beautification or of architectural design but to make the environment more viable (Algarni et al., 2022). Indeed, the green roof system is a natural insulation against heat, cold, noise and which at the same time makes it possible to fight against

the various effects of global warming, urbanization and energy consumption (Park et al., 2022). A study showed that its surface temperature is up to 15K lower than that of the commonly used roof (Karachaliou et al., 2016). Beyond acting only on the building, it also influences the urban area by participating in the reduction of its temperament, its pollution rate and the attenuation of the heat island effect (Aboelata, 2021).

Benefits of Green roofs

The green roof has many benefits not only for the people who spend time in the building but also for the city in which it is located. Among these there are few sites:

- The reduction in the level of CO and CO2 and certain atmospheric pollutants through its supply of oxygen which improves air quality.
- Allows temperature regulation
- Allows the preservation and development of biodiversity as well as the creation of a habitat for wildlife.
- Allows constant contact with nature in an urban environment
- Provides protection against bad weather because it provides insulation
- Gives aesthetic value to the building and changes the landscape of the city
- Enhances the house and adds its value even for sale
- The regulation of the flow of rainwater is a great advantage because the roofs receive a considerable quantity of rainwater, and the green roof allows a large part of this water to be absorbed through the plants and slowly evacuate the rest. This helps reduce flooding and drainage problems.
- Helping to mitigate the heat island effect.
- The increase in oxygen levels in the atmosphere (Algarni et al., 2022)
- cooling the building and minimizing its energy consumption (Aboelata, 2021)
- Attenuation of the sun's rays and temperature management in summer by keeping the roof cold and reducing the cold in winter (Algarni et al., 2022).

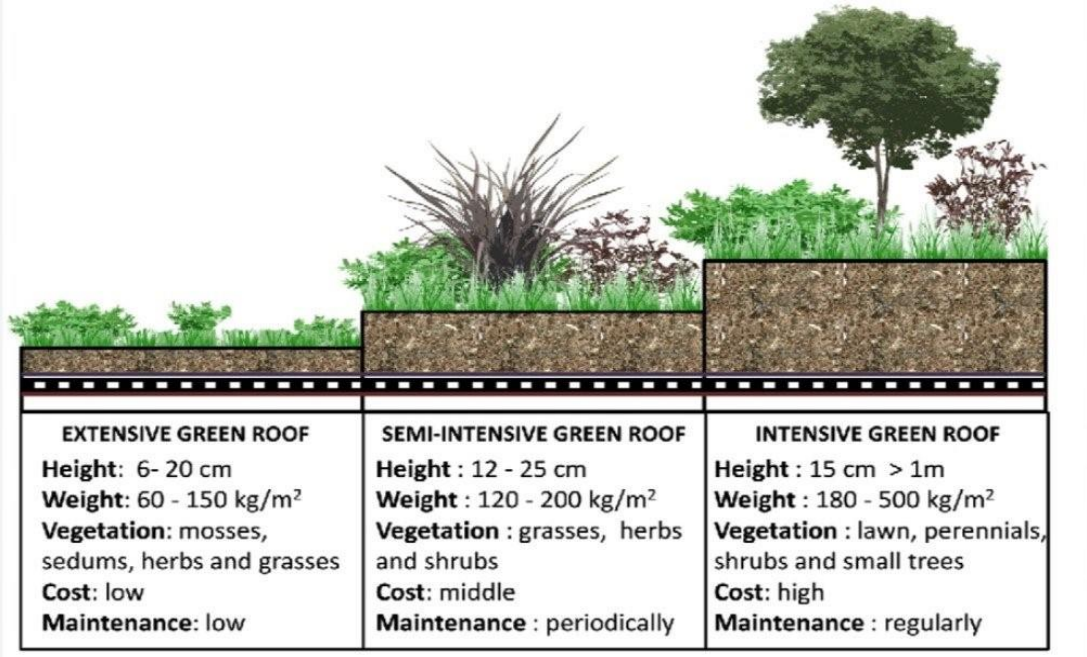
Type of Green Roof

There are three types of green roofs depending on the size of their thickness. There is the extensive roof or green roof, the semi-intensive roof or light garden roof and the intensive roof or garden roof which is use for parks and gardens including Urban Agriculture.

- **Extensive Green Roof:** The first type of roof which is the extensive green roof is characterized by the dimension or depth of its substrate which is smaller than for the other types and these are plants which require little maintenance which are planted there such as sedums, herbs, fatty (Figure 16). Extensive green roofs are generally constructed in a way that many people cannot access them, and their installation is easy, less expensive and easy to maintain (Ozkan, 2021).
- **Semi-Intensive Green Roof:** The second type is the semi-intensive green roof which is characterized by a substrate which has an intermediate depth between extensive and intensive. This type can accommodate plants such as succulents, herbs and shrubs and their maintenance depend on the ecological requirements of the different plants chosen (Ozkan, 2021). Their installation costs more than for an extensive roof with periodic maintenance (Figure 16).
- **Intensive Green Roof:** The third type, which is the intensive roof, is characterized by a substrate which has a great thickness compared to other types of green roofs which also implies a great weight. This type of roof requires a lot of maintenance because it can accommodate several types of plants such as shrubs and small trees and it can be used as a garden, park or even for the practice of agriculture (Ozkan, 2021). Its installation is expensive given its weight, the materials and the labor that it requires to build this type of roof (Figure 16).

Figure 16.

Green Roof Types based on the International Green Roof Association (IGRA)



(Ercan et al., 2021)

Components of Green Roof

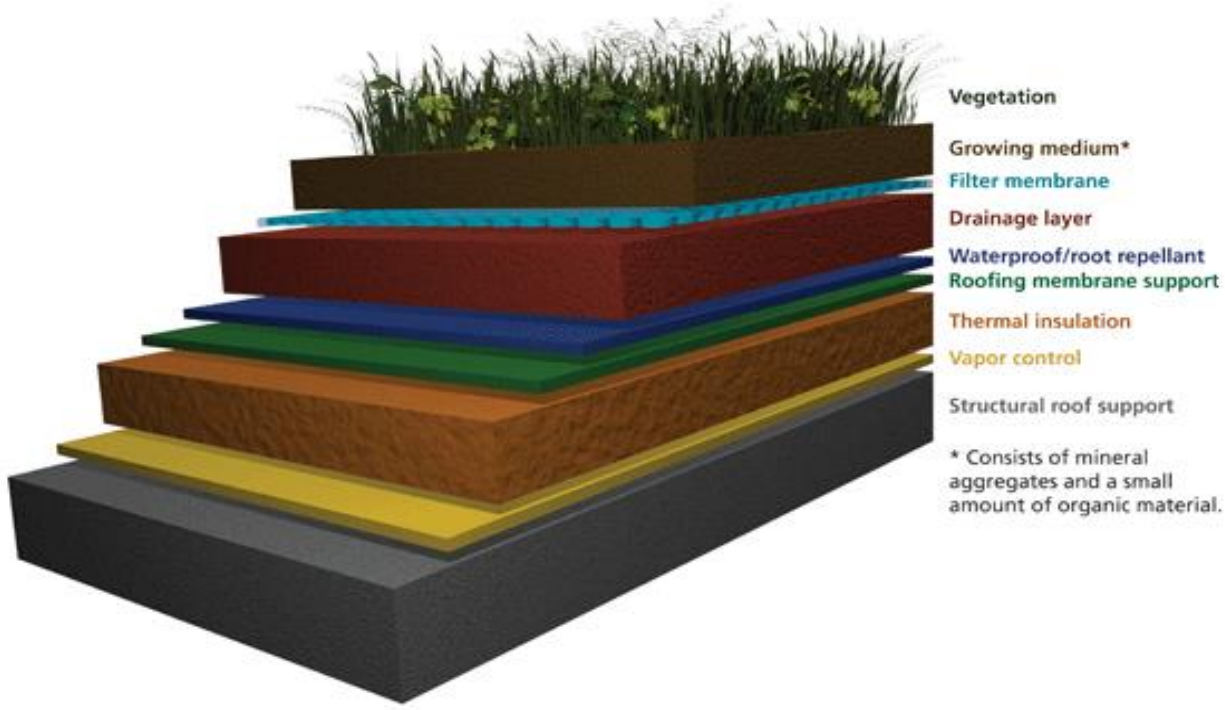
A green roof is a system which is made up of several parts which ensure that the roof remains waterproof and efficient without becoming harmful to the building. Indeed, the green roof system is composed of diversified vegetation planted on a substrate and below this is the filtering layer, the draining layer, an anti-root barrier as well as the waterproofing membranes which are layers that protect the building against infiltration (Figure 17) (Jamei et al., 2021). These elements are very important for the proper functioning of the green roof and for its efficiency.

- **The substrate:** It is the growth medium for vegetation and is a mixture of soil and certain nutritious organic compounds. Its composition and layout are designed to facilitate a natural environment.
- **The filter layer:** It helps protect the drainage layer by preventing certain elements of vegetation from penetrating it.

- **The drainage layer:** It allows the evacuation of excess water whether for watering or rainwater so that the roots are not damaged and to avoid infiltration into the building.
- **The root barrier:** It prevents roots from reaching the waterproofing membranes because there are certain plants whose roots are aggressive and can cause problems with the protective components of the roof.
- **The vapor barrier:** It helps protect the roof against humidity in order to avoid mold
- **Thermal insulation:** It helps protect the building against the sun's rays by stopping them so that they do not penetrate inside to cause heat.

Figure 17.

Components of Green Roof



(National Park Service, 2022)

Benefits of Green Roof for Offices

Office buildings have a great impact on the environment given the different materials they use and the amount of energy they consume due to their activities. This is why a green solution is the best way by which this impact will be minimized, and the use of the green roof is

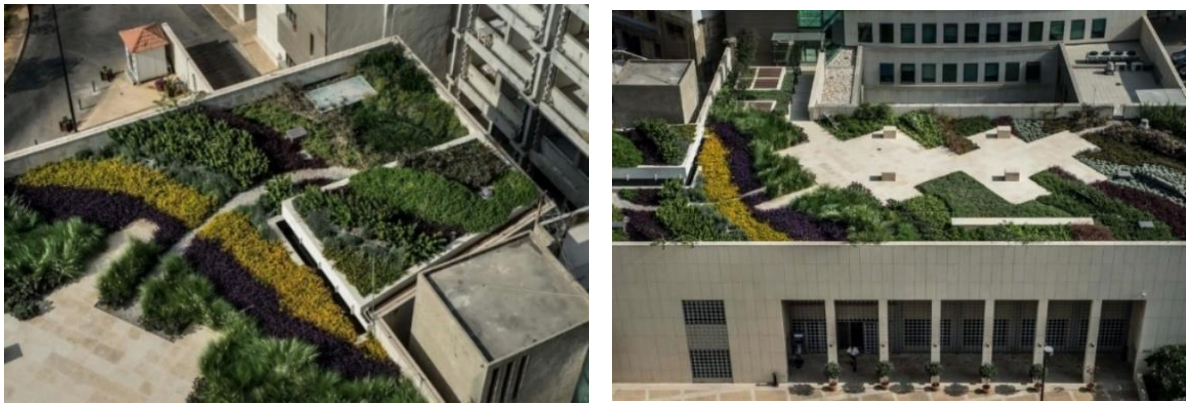
one of the effective ways to achieve this because the system presents benefits for offices which are:

- Improving the working environment by providing an environment that has good air quality and effective ventilation
- Reduction of noise diffusion as well as insulation of sound waves, which will allow efficient work without sound interference from outside
- Reducing the energy consumption of the building and its carbon footprint
- Thermal management of the building between summer and winter while reducing solar radiation, which allows companies to reduce the use of air conditioning and heating
- Management of passing rainwater
- Provides a natural environment for employees that can be a place of rest, relaxation and familiarization.

The green roof for office buildings presents ecological, economic and social advantages and allows them to be a place of beauty and sustainability at the same time.

Figure 18.

Example of Office Buildings with Green Roofs, The Central Bank of Lebanon



A. *Detailed view of the roof with the various plants*

B. *The interesting contrast between the building and its roof*

(Green Studio, 2024)

Related Research

For the conduct and research of this work, several works were consulted. Below are the various researches related to this study.

Magill, J. D., Midden, K., Groninger, J., & Therrell, M. (2011). A history and definition of green roof technology with recommendations for future research. *Southern Illinois University Carbondale, [online] http://opensiuc. lib. Siu*.
This work explains the history of the green roof, its evolution and its consideration over time.

Browning, W.D., Ryan, C.O., Clancy, J.O. (2014). 14 Patterns of Biophilic Design. New York: Terrapin Bright Green, LLC.
This work is very important for this study because it explains the history of biophilic design and the 14 patterns of biophilic design as well as their classification.

Candido, C., Chakraborty, P., & Tjondronegoro, D. (2019). The rise of office design in high-performance, open-plan environments. *Buildings*, *9*(4), 100.
This work explains the importance of taking into account the design of a workspace as well as its specific spatial organization.

Ascione, F., De Masi, R. F., Mastellone, M., Ruggiero, S., & Vanoli, G. P. (2020). Green walls, a critical review: Knowledge gaps, design parameters, thermal performances and multi-criteria design approaches. *Energies*, *13*(9), 2296.
This source gives important information about green walls and its different types and components

Barbiero, G., & Berto, R. (2021). Biophilia as evolutionary adaptation: An onto-and phylogenetic framework for biophilic design. *Frontiers in psychology*, *12*, 700709.
This work explains the theory of biophilia and its meaning as well as biophilic design.

Andriot, P. & Larceneux, F. (2022). VIII / La qualité des immeubles de bureaux : pourquoi et comment la mesurer ? Proposition d’un indicateur de qualité globale. Dans : Dauphine Recherches en Management éd., *L'état du management 2022* (pp. 84-96). Paris : La Découverte.

This source of information explains what an office building should be like.

Gao, W., Jin, D., Wang, Q., & Zhu, P. (2023). Integrating user-centered design and biophilic design to improve biophilia and intelligentization in office environments. *Buildings*, *13*(7), 1687.
This work explains biophilic design in an office building and nature in a workspace.

Wijesooriya, N., Brambilla, A., & Markauskaite, L. (2023). Biophilic design frameworks: A review of structure, development techniques and their compatibility with LEED sustainable design criteria. *Cleaner Production Letters*, *4*, 100033.
This source explains the principles and dimensions of biophilic design.

Shahhoseini, H., Arvaneh, N., & Mousavi Samimi, P. (2023). Identifying greenery preferences in office buildings' indoor environments from the perspective of employees (case study: Tabriz city). *Armanshahr Architecture & Urban Development*, *16*(43), 93-104.
This work explains the importance of plants in indoor spaces and specifically for workspaces with user preferences.

Zhong, W., Schroeder, T., & Bekkering, J. (2023). Designing with nature: Advancing three-dimensional green spaces in architecture through frameworks for biophilic design and sustainability. *Frontiers of Architectural Research*, *12*(4), 732-753.
This work allowed us to understand the importance of designing with nature and the different types of nature that we can have in space.

CHAPTER III

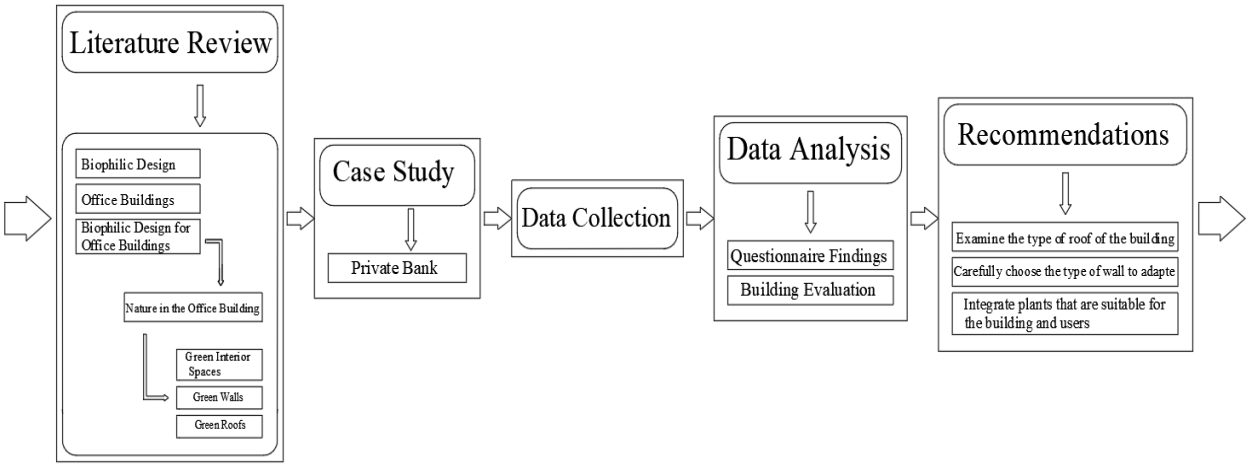
Methodology

This third chapter is mainly concerned with the research methodology used for the collection and analysis of data with the different tools used as well as the procedures. It contains research design, data collection tools, data collection Procedures and data analysis procedures.

To carry out this study, by responding to the research questions, it is important to carefully examine the different aspects which concern this subject in order to find as much detail as possible and also turn to the different office buildings which have used biophilic design in such a way as to have not only theoretical elements but also examples of practical application. This research will allow us to provide information on the mechanisms to be put in place to design an ideal working environment conducive to the development of employers and the company. This part of the work therefore focuses on the research methodology to be used to achieve the research objectives. The figure 19 describes the process and working method used in the thesis.

Figure 19.

Figure 1. Explanatory Diagram of the Methodology and Work



Research Design

For the methodology, the mixed method of triangulation design will be used because it is a type of design in which different data from several sources of information are collected and complement each other in order to form a coherent whole on the same subject. To do this, the use of qualitative and quantitative data is necessary to have maximum information on the subject covered.

• **Qualitative data:** For the conduct of this study in the collection of different data and their analysis, the qualitative method was used to understand the different implications through details and contexts. Thus, the method was adopted first for an in-depth analysis of the different literary reviews which address the subject of biophilic design, its importance and its contribution to the field of architecture, in office buildings and in the city. Then, the observation technique was applied to the case study which is a private bank in Kolwezi to have more details on this office building.

• **Quantitative data:** Quantitative data is based on a survey conducted through a questionnaire to collect as much information as possible from those who usually use office buildings.

Participants

For the quantitative part, the sample of the study is made up of private banking users in particular. The participants can be nationals or even internationals, men and women over 18 years old and it does not depend on the position held in the company, so everyone could answer. The procedure was simple, after the manager accepted the search request, the questionnaire was sent to them as a link, and they just had to answer it and send it back. The bank has about 52 members and out of this number, a sample of 30 members responded to the questionnaire.

Data Collection Tools

Given the fact that this study required several pieces of information from several sources depending on the methodology used several tools were used to collect as much information as possible. For the literature reviews, search tools mainly Google Scholar which is a tool which brings together several pieces of information from different disciplines was used for this study.

For the observation part, visual elements were collected and Google Earth which is a tool which allows to see the whole earth in general and specific places in particular with considerable precision was used to observe the private bank building and its surroundings and more precisely the roof. Quantitative data collection was done using the Google Forms tool which allows to create online forms.

Data Collection Procedures

Data collection, which is a rational approach to gathering information on a particular topic, was based on literature reviews obtained from reliable sources of information, which specifically meet the terms of this study and on the findings of the case study. Visual examples of data were also collected in order to have as much useful information as possible. Indeed, to evaluate the building, it was necessary to collect images of the building made available by the bank and also with the help of google earth. A questionnaire including questions based on biophilic design and adaptation of natural elements in an office building was prepared and sent out to directly collect some data on the case study. The questionnaire consists of 21 questions grouped into three sections, the first section of which includes 5 questions on general information provided by the participants. The second section includes 8 questions about biophilic design in an office building and the third section consists of 8 questions about greens in an office building. Apart from the first section where the questions were adapted to the participants' situation, the last two sections were designed using the Likert scale. The Likert scales that were used are the 3-point scale where participants have three options and the 5-point scale where participants have five options.

Data Analysis Procedures

Data analysis is an approach that involves looking at the information gathered to bring out certain information or highlight certain aspects that were not necessarily remarkable. For this study, it was carried out on the basis of data collected from literary journals and other sources of information collected and on observational data that provided a basis for making an evaluation based on the biophilic design models of the first category and on the three systems chosen. Indeed, the analysis of this study was done in two parts, the first part of which concerns the

analysis of the data collected from the questionnaire which was carried out according to a certain framework. For this analysis, since the questionnaire has 3 sections, the data from each section was analyzed to establish a success percentage that shows the ratio between the number of responses and the number of people who participated in the survey.

$$\text{Success Percentage} = \frac{\text{Nomber of responses}}{\text{Nomber of participants}} \ 100$$

The second part of the analysis concerns the evaluation of the building on the basis of the biophilic design patterns according to their categories and especially on the first from which the three systems were drawn. Also, on the evaluation of the building, the evaluation based on green walls, green roofs and green interior spaces was also analyzed. The building's ratings were based on a rating scale that is poor, fair, good or absent.

Good: The Good rating is awarded when the desired element is present and fully meets the standards sought
Fair: The Fair rating is awarded when the element is present and plays its role but without meeting all the necessary conditions
Poor: The Poor rating is awarded when the element is present but not generally effective.
Absent: The absent rating is assigned when the searched element is not there

According to these different analyses, it was therefore possible to draw a conclusion as well as the necessary elements of recommendations on biophilic design and its contribution as well as its adaptation in an office building in Kolwezi.

CHAPTER IV

Biophilic Design in the Office Building in Kolwezi

This fourth chapter includes the description of the case study environment, which involves information about the city of Kolwezi as well as its history, location, climatic situation, office buildings and the chosen private bank.

Background of Kolwezi

The city of Kolwezi is the capital of the Lualaba province in the Democratic Republic of Congo. Congo is the largest country in Sub-Saharan Africa, located in the center of the continent, it is a country which has significant natural resources such as hydroelectric potential, very great biodiversity, one of the largest forests tropical world and minerals such as copper and cobalt (The World Bank, 2024). Indeed, Congo is an important country in the mining sector because it supplies several mining products such as gold, diamonds, copper and many others and it is the largest supplier of Cobalt in the world, i.e. 71% of the global stock of this material which can be used in the production of lithium-ion batteries which can be used for electric cars, which will make it possible to reduce or even eliminate fossil fuels (Deberdt, 2021). A large part of this mineral reserve comes from the Lualaba province, more precisely from Kolwezi, which is a town directly linked to mining (Maka & Kantenga, 2018). This exploitation attracts many investors from inside and outside the country, researchers who carry out studies on natural resources and their urban, national and even international impact (Ikonga-Kapenda et al., 2016). It also attracts people from rural areas and other provinces of the country in search of work (Maka & Kantenga, 2018). This exploitation is important for the country's economy and the mining town of Kolwezi is often considered the heart of the national economy because it contains significant mineral deposits (Ikonga-Kapenda et al., 2016).

Mining, which before was done artisanally, is now also done industrially (Maka & Kantenga, 2018), which has caused many people to leave the agricultural sector for the city and this movement of the population is at the basis of the demographic development of the city (Ikonga-Kapenda et al., 2016). This activity presents socio-economic advantages for the city and the country, but it has consequences on the movement of the population which causes social disruption, on the environment by making the city ecologically sensitive because mining can be

at risk. basis of atmospheric pollution due to emissions into the air and gas, the reduction in biodiversity as well as radioactive contamination due to uranium ores (Nguza & Katal, 2016).

History of the City of Kolwezi

The place where the town of Kolwezi is located today was previously a savannah with small villages surrounding it, but after the discovery of the wealth and large quantities of mineral resources with which it is endowed, it became a mining center (Antippas, 2017). The town was created in 1937 by the Belgian mining company called Union Miniere du Haut-Katanga (UMHK) and Kolwezi was considered at the time as the first workers' town for quarry workers (Geenen, 2018). At that time, the economy of the province of Katanga was focused on the Union Miniere du Haut-Katanga and the city developed rapidly and workers' quarters were created not far from the factories and quarries (Antippas, 2017). With the opening of another quarry, the company decided to create other workers' towns such as the Musonoi town in 1945, the UZK town in 1953, the Ruwe town today known as the Mutoshi town in 1956 and after the installation of an electrolysis plant, the Luilu city was built nearby in 1958 and finally the Kapata city in 1962.

Thanks to the addition of all these workers' cities, Kolwezi became larger, and it was only in 1976 with the merger of other territories such as Mutshatsha and Lubudi that it officially became an urban-rural town with two communes including the commune of Dilala and the commune of Manika (Ikonga-Kapenda et al., 2016). With the development of the city, its population also increased as people had a desire to work in a mining area and in 1984 it became the fourth largest city in the country and the second largest city in the Katanga province after the city of Lubumbashi (Mthembu-Salter, 2009). The town planning of the city was done in such a way as to separate the Belgian colonizers from the Congolese workers and the center of the city was the business district and right next to it were their areas of residence and the workers lived in the cities near their workplace and today these places are heritage (Mthembu-Salter, 2009).

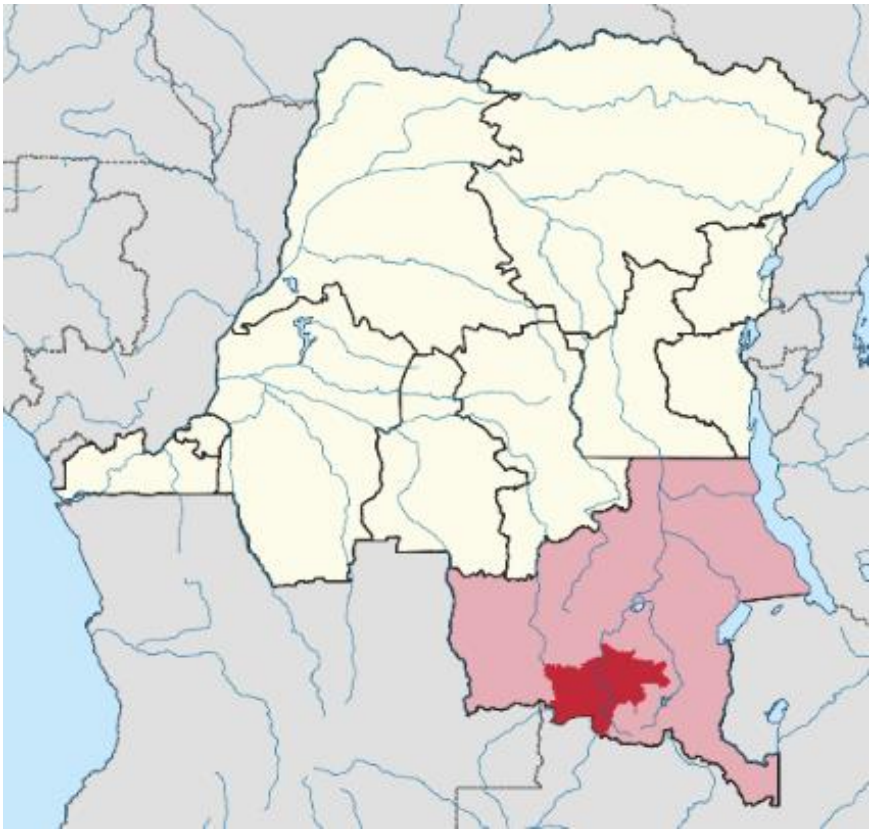
During 2005, a provincial division plan was published by a commission which stipulated that the town of Kolwezi, which was a town in the province of Katanga, would be linked to the district of Lualaba to form a province (Gobbers, 2022). The ethnic organizations did not agree on the division above all of the province of Katanga (Gobbers, 2021), and others were against the connection of Kolwezi with the Lualaba district, but they understood that its economy depended

mainly on Kolwezi (Gobbers, 2022) and it was in 2015 that Lualaba became a province with Kolwezi as its capital.

Location of the City of Kolwezi

Figure 20.

The T*own of Kolwezi*



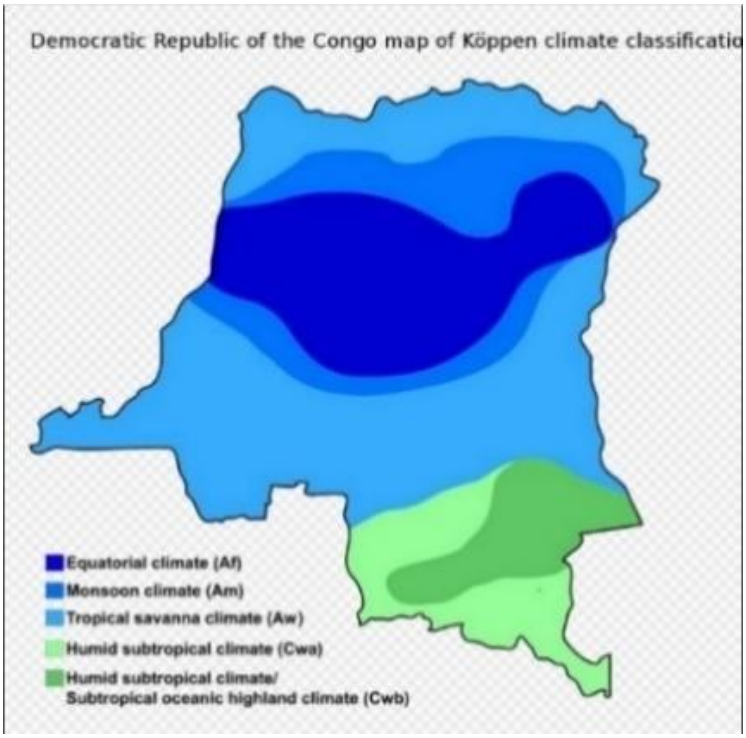
(Wikipedia, 2024)

The mining town of Kolwezi is a large mining center with an area of 213 km^2. It is located in the South-East of the country, on the Manika plateau with an average altitude of 1500 meters (about 4921.26 ft) above sea level (Atibu et al., 2021). Its geographic coordinates are 26 degrees East Longitude and 11 degrees South Latitude (Kikatwe & Mutombo, 2016). The city is bordered to the north by the province of Haut-Lomami, to the south-east by Zambia and Haut-Katanga and to the south-west by the former district of Lualaba (Figure 20) (Ikonga-Kapenda et al., 2016).

Climate Situation of Kolwezi

Figure 21.

The Köppen Climate Classification for the Congo

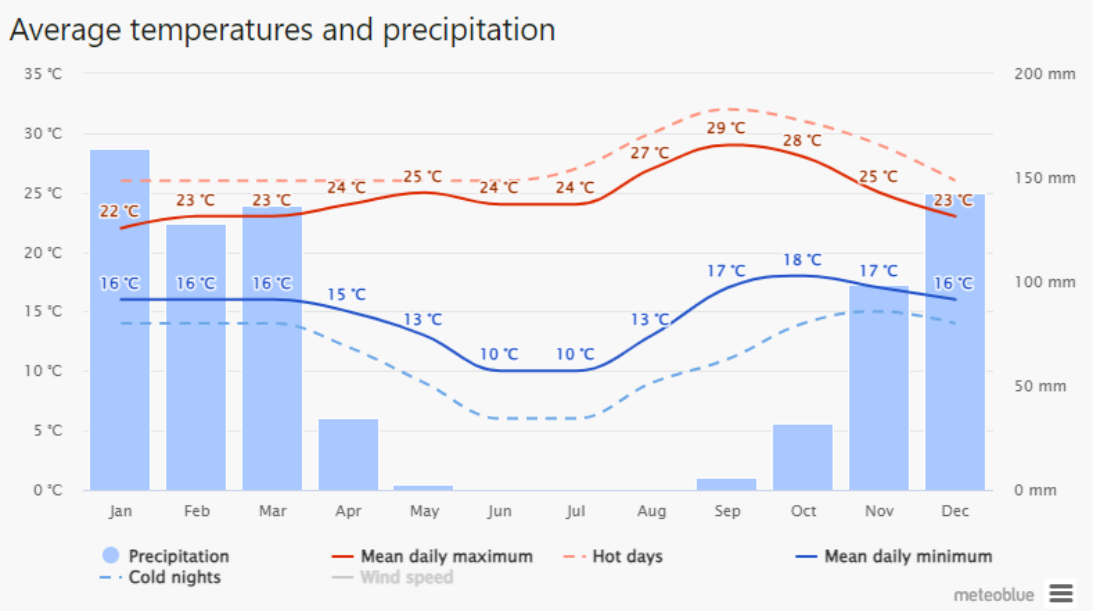


(Commons, 2021)

The Democratic Republic of Congo is a country crossed by several types of climates, of which the South where the Lualaba province is located is crossed by the tropical climate. According to the Köppen classification which is a globally recognized classification system based on the temperature, precipitation and vegetation of a place, the city of Kolwezi is of the type (Cwa) that is to say that it is a Zone of humid subtropical climate with an average temperature of 22°C (Figure 21) (Nationalgeographic, 2023). The climate is characterized by the presence of two seasons which are the rainy season and the dry season. The rainy season is longer than the dry season with periods of heavy precipitation from November to April and a dry season which is more remarkable from the month of June to August characterized by a rather clear sky and a lot of rain and wind (Figure 22) (Meteoblue, 2023). The climate is characterized by a drop in temperature at night and by high temperatures during the day and the average temperature during the year varies between 10°C and 30°C but there are years where the minimum can reach 6°C and the maximum 34°C (Figure 22).

Figure 22.

Average Temperatures and Precipitations in Kolwezi



(Meteoblue, 2023)

Office Buildings in Kolwezi

Office buildings are spaces reserved for different professional activities, the size of which often depends on the number of employees. They are important and are generally designed in such a way that they can reflect the type of work being done and those in Kolwezi are no exception. In the city, several mining companies are established with factories or mines but in most cases, there are administrative areas where it is possible to find organized office spaces. Overall, office buildings in Kolwezi are organized in terms of spatial organization like all other offices but they are not designed with the principles or patterns of biophilic design.

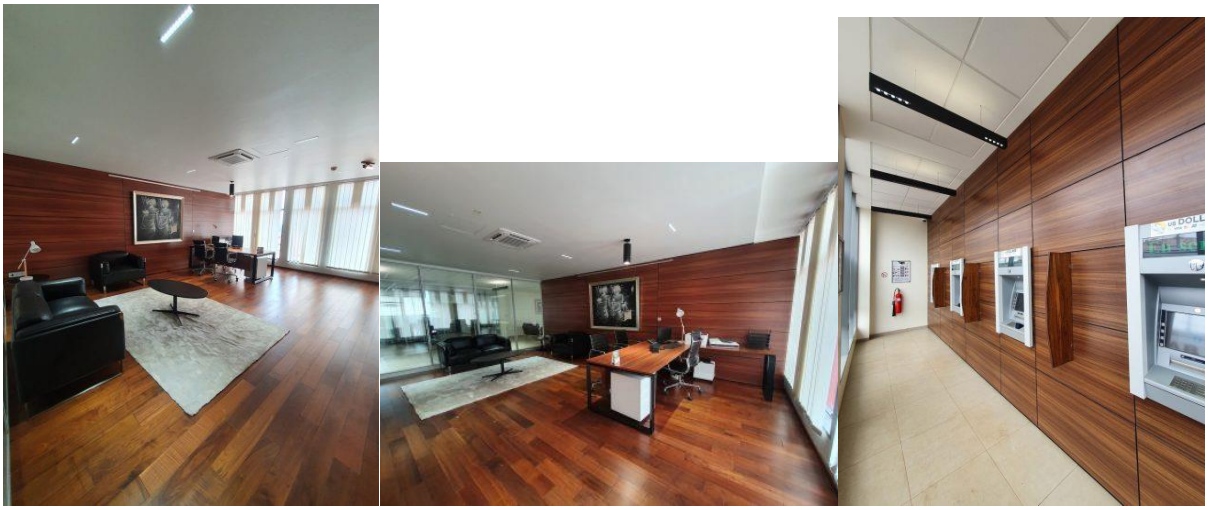
The private Bank

The case study of this research is a private bank that has been established for a few years now in the city of Kolwezi. It is a merchant bank for miners to contribute to the development of the capital of the province of Lualaba. The building is made up of 3 floors and four ATMs. The first floor is intended for banking operations for individuals or customers, the second is reserved for corporate clients and another compartment of the bank is intended for private banking. The

building presents a good working environment but nevertheless, as can be seen in the Figure 23, it is a building whose design has not been made according to biophilic patterns.

Figure 23.

The Interior of the Private Bank Building



(aapl architecture, 2020)

CHAPITER V

Findings and discussion

This fifth chapter includes the evaluation of the results, which includes the results of the questionnaire, the evaluation of the building and the discussion.

Evaluations of findings

The evaluation is done in two parts (Table 2), the first is carried out on the basis of the questionnaire data and the second is an evaluation of the building made on the basis of biophilic design patterns and on the three selected elements which are green interior spaces, green walls and green roofs.

Table 2.

The Two Parts of the Results Evaluation

Evaluation of findings	
Part 1: Questionnaire Findings	Section 1: The general information of the participants Section 2: Biophilic design in the office building Section 3: The importance of plants in the office building
Part 2: Building Evaluation	Evaluation of the private bank building based on biophilic design patterns Evaluation of the building based on the three systems which are green interior spaces, green walls and green roofs.

Part 1: Questionnaire findings

For this work, the qualitative method and the quantitative method were chosen to conduct the research in a concise manner. The quantitative part was done using a questionnaire written with the Google Forms tool which had 3 sections. The first section was general information about the participants, the second was about biophilic design in the office building and the third about greens in the office. According to the information received regarding the number of workers in the bank, the structure has approximately 52 members of which a representative sample of 30 members responded to the survey.

Section 1: General Information

The section (Table 3) which deals with the general information of the participants is important because it allows us to know the type of participant and in the case of this study in particular the information also helps to know the time they spend in the building.

Table 3.

Results about General Information

General Information Results			
Questions	Number (30)	Percentage	Evaluation
Gender	Male (17) Female (13)	56,7 % 46,3 %	Most bank workers are men
Age	18-30 (14) 31-40 (11) 40-50 (5) 50-60 (0) 61 and over (0)	46.7 % 36,7 % 16,7 % 0 % 0 %	Most of the participants are aged between 18-30 but the maximum age does not exceed 50 years.
How long have you been working at the company?	0-1 year (2) 1-5 years (19) 5-10 years (9) 10-20 years (0) 20 years and over (0)	6,7 % 63,3 % 30 % 0 % 0 %	Most of the participants have spent between 1-5 years at the bank
How many days a week do you spend at work?	3 days (0) 4 days (1) 5 days (1) 6 days (25) 7 days (2)	0 % 3,4 % 3,4 % 86,2% 6,9%	Most participants work 6 days a week
How much time do you spend in the office on a working day?	Less than 6 hours (1) Between 6 and 7 hours (0) 8 hours (4) 9 hours (9) More than 9 hours (16)	3,3 % 0 % 13,3 % 30 % 53,3 %	More than half of participants work more than 9 hours per day

For this first section, the success percentage, which is the ratio between the number of responses and the number of participants, is 100%

According to the results obtained thanks to the questionnaire, it is possible to note that more than half of the participants are men, and the other part are women. They are aged between 18 and 50, many of them are rather young and they have had no more than 10 years in the company. Some have been there for between 5 and 10 years maximum, others, more than half of whom have worked there for one to 5 years and there are even those who have had less than a year there. Most of them work 6 days a week and some spend 6 to 7 hours a day in the office, others 8 to 9 hours and still others in large numbers spend more than 9 hours of the time in the office.

Section 2: Biophilic Design in the Office Building

The second section includes questions on biophilic design in office buildings to better understand how it is perceived by workspace users. Table 4 clearly shows the different responses obtained for this section.

Table 4.

Result about Biophilic Design in the Office Building

Biophilic Design in the Office Building Results			
Questions	Number (30)	Percentage	Evaluation
Is Biophilic design important?	Strongly Agree (12) Agree (9) Neutral (8) Disagree (1) Strongly Disagree (0)	40 % 30 % 26,7% 3,3 % 0 %	Most participants agree that biophilic design is important
Is it important today to take it into account in the built environment?	Strongly Agree (15) Agree (8) Neutral (6) Disagree (1) Strongly Disagree (0)	50 % 26,7 % 20 % 3,3 % 0 %	They find it important to take design into account in the built environment
What do you think about the integration of biophilic design into the workspace?	Strongly Agree (18) Agree (9) Neutral (2) Disagree (1) Strongly Disagree (0)	60 % 30 % 6,7 % 3,3 % 0 %	Most participants agree with the integration of biophilic design into the workspace

What do you think about the presence of natural elements in your workspace such as an aquarium, a fountain, plants?	Strongly Agree (23) Agree (6) Neutral (0) Disagree (1) Strongly Disagree (0)	76,7 % 20 % 0 % 3,3 % 0 %	Most of them agree with the integration of natural elements into the work space
Does the design of your office impact your performance?	Yes (24) I don't know (1) No (5)	80 % 3,3 % 16,7 %	For the most part, workplace design has a considerable impact on their performance
Is daylight important to you at work?	Yes (27) I don't know (1) No (2)	90 % 3,3 % 6,7 %	Daylight is important in the workplace for the majority
Does the painting of your workplace impact your concentration?	Yes (23) I don't know (2) No (5)	76,7 % 6,7% 16,7 %	For more than 70% of participants, paint has an impact on concentration
Is natural ventilation better than artificial?	Yes (24) I don't know (3) No (3)	80 % 10 % 10 %	The majority prefer natural ventilation more than artificial ventilation

For the second section, the success percentage is 100%

Biophilic design, which is an architectural concept that is becoming more and more important in workspaces, is for most participants an important concept to consider in the design of buildings and more particularly office buildings and the other participants are rather neutral on this subject. For most of them the presence of natural elements in workspaces such as aquariums, fountains, plants and other elements are welcome. For them, the working environment, the design, the daylight and the painting of their workspace are important because they have an impact on their concentration and their performance at work and they find that natural ventilation

is preferable to artificial ventilation. But there are also those who, even in small numbers, can adapt to any work environment and produce results.

Section 3: Greens in the Office Building

The third section (Table 5) includes questions about greens in offices because the information obtained helps to understand how plants are perceived and what importance their presence has in office buildings.

Table 5.

Results about Greens in the Office Building

Greens in the Office Building Results			
Questions	Number (30)	Percentage	Evaluation
What do you think about the presence of plants in the workplace?	Strongly Agree (21) Agree (9) Neutral (0) Disagree (0) Strongly Disagree (0)	70 % 30 % 0 % 0 % 0 %	All participants agree with the integration of plants in the workplace
What do you think about integrating a green wall to the office building?	Strongly Agree (19) Agree (8) Neutral (2) Disagree (1) Strongly Disagree (0)	63,3 % 26,7 % 6,7 % 3,3 % 0 %	The majority agree to the integration of green walls in the office building
What do you think about integrating a green roof on an office building?	Strongly Agree (20) Agree (4) Neutral (6) Disagree (0) Strongly Disagree (0)	66,7 % 13,3 % 20 % 0 % 0 %	Most participants agree with the integration of a green roof on the office building
Are places that have plants better than places that don't?	Yes (27) I don’t know (1) No (2)	90 % 3,3 % 6,7 %	90% of participants find that places with plants are better than those without them

Are plants important for human well-being and the environment?	Yes (30) I don't know (0) No (0)	100 % 0 % 0 %	All workers think that plants are important for well-being and the environment
Would you like to have plants in your workspace?	Yes (29) I don't know (1) No (0)	96,7 % 3,3 % 0 %	More than 95% of participants would like to have plants in their office
Do you think that the presence of plants in an office can have a social, economic and environmental advantage?	Yes (28) I don't know (2) No (0)	93,3 % 6,7 % 0 %	The majority think that plants in an office have economic, social and environmental advantages
Do you think that contact with nature has positive effects on your work?	Yes (28) I don't know (1) No (1)	93,3 % 3,3 % 3,3 %	Most participants think plants have an effect on their work

For the third section, the success percentage is 100%

Plants are important elements of nature whose virtues are increasingly known and for most participants the places which have plants are preferable to those which do not have them, and they all agree with the presence of plants in workspaces because plants are important for human well-being and the environment. Indeed, the presence of plants has a considerable impact and can present social, economic and environmental benefits and contact with nature has a positive influence on work, which is why most of them would like to have plants in their workspace. Most participants completely agree with the integration of green roofs and green walls in office buildings and the minority is rather neutral regarding this integration.

Part 2: Building Evaluation

This second part concerns the evaluation carried out on the basis of biophilic design patterns firstly and secondly on the three green systems selected in the first category of patterns.

Evaluation of the Private Bank based on biophilic design patterns

This part of the work focuses on the evaluation of the case study chosen based on 14 biophilic design patterns to determine if the building meets the different criteria (Table 6). The evaluation is based on a classification scale which can be poor, fair, good or absent.

Table 6.

Biophilic Design Patterns Ranking Scale (poor, fair, good or absent).

Good: The Good rating is awarded when the desired element is present and fully meets the standards sought
Fair: The Fair rating is awarded when the element is present and plays its role but without meeting all the necessary conditions
Poor: The Poor rating is awarded when the element is present but not generally effective.
Absent: The absent rating is assigned when the searched element is not there

	14 patterns	Evaluation	Ranking scale
Nature in space	1. Visual Connection with Nature	There is a visual connection with nature, but it is not enough	Poor
	2. Non-Visual Connection with Nature	The non-visual connection with nature is weak	Poor
	3. Non-Rhythmic Sensory Stimuli	Non-rhythmic sensory stimuli are present but not sufficiently	Poor
	4. Thermal & Airflow Variability	Thermal and air flow variability is dependent on the building environment and air conditioning	Fair
	5. Presence of Water	There is no water feature in the building or outside	Absent

	6. Dynamic & Diffuse Light	The building has large openings to the outside and offers plenty of light inside.	Good
	7. Connection with Natural Systems	There is a connection with the natural system but it is weak	Poor
Natural analogues	1. Biomorphic Forms & Patterns	In the layout of the bank and the shape of the building,	Absent
	2. Material Connection with Nature	there is no biological evocation whether in the	Absent
	3. Complexity & Order	shape, the different materials or the painting.	Absent
Nature of the space	1. Prospect	The spatial organization of	Absent
	2. Refuge	the building does not give the	Absent
	3. Mystery	feeling of being linked to	Absent
	4. Risk/Peril	nature and does not provide the feeling of mystery, peril, risk.	Absent

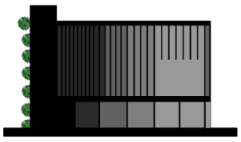
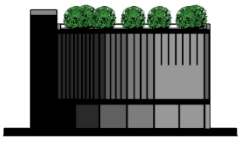
Evaluation of the Private Bank based on the three systems

Starting from the 14 patterns of biophilic design which are grouped into three categories, the first which is nature in space was chosen and in which three systems were selected for the conduct of this research. The evaluation was made based on the criteria which define the three systems which are green interior spaces, green walls and green roofs (Table 7). The evaluation is based on a classification scale which can be poor, fair, good or absent.

Table 7.

Ranking Scale of the Three Systems (poor, fair, good or absent)

Good: The Good rating is awarded when the desired element is present and fully meets the standards sought
Fair: The Fair rating is awarded when the element is present and plays its role but without meeting all the necessary conditions
Poor: The Poor rating is awarded when the element is present but not generally effective.
Absent: The absent rating is assigned when the searched element is not there

Systems	Evaluation	Ranking scale	Suggestions
Green Interior Spaces	The building has plants but in small quantities	Poor	
Green Walls	The building does not have a green wall	Absent	
Green Roofs	The building does not have a green roof	Absent	

Green Interior Spaces

Figure 24.

Plants in the Building

(aapl architecture, 2020)

Green interior spaces are areas inside buildings whose layout also includes plants. Therefore, it is possible to notice that in the layout of the building (Figure 24), there is the presence of certain plants. Plants have a positive effect inside as well as outside but to really benefit from these different advantages they must be in sufficient quantity, which is not the case for this building. There are certainly plants but in small quantities compared not only to the number of users but also to the size of the building and they are not found everywhere in the building, but just in a few places.

Green Walls

Figure 25.

Interior Walls of the Building

(aapl architecture, 2020)

Figure 26.

Exterior Walls of the Building

(Hugues Herrmann, 2021)

Green walls are systems that are among the green infrastructures that allow nature to be brought into the building and they can be inside as well as outside. However, according to the information received and considering the visual elements presented (Figure 25 and Figure 26), it is possible to note that the private bank building does not have a green wall either inside or even outside. Considering how the green wall works and according to the different types, it is possible to integrate it to bring more nature into the building.

Green Roofs

Figure 27.

The Roof of the Building

(Google Earth, 2024)

According to this image of the private bank building (Figure 27), it can be clearly seen that there is no green roof. However, there is a possibility of integration given the potential that the roof of the building presents. Indeed, most of the roofs in the surrounding area are sloping roofs while that of the bank is a terrace roof which can support a greening system.

Discussion

According to research done in general, it has been proven that human beings spend on average 85% to 90% of their time inside a building and this often pushes people to pay more attention to the quality of the air and comfort taking into account the fact that several substances can also concentrate in the building which is not good for health. Another aspect which must also be considered is the fact that the built environment has imposed a certain limit on contact between humans and their natural environment and this is not good for the well-being of living creatures.

Therefore, among all the types of built environment that can cause this separation, this work is primarily focused on office buildings that are used by individuals for several hours of the day. According to the results obtained through different sources of information and especially those coming from the case study, it was noted that workers spend a lot of time in the building, almost the majority of their days and this situation largely favors disconnection between them and the natural environment. To remedy this situation which has been observed throughout the world, several solutions have been put in place, notably the contribution of natural elements through biophilic design in buildings with a view to promoting a reconnection but in the chosen study case, this attempt is still weak given the number of users and the size of the building. According to the results obtained through the survey, it is possible to see that biophilic design is really an important concept which can have a considerable impact in office buildings if it is really understood at its fair value according to its various contributions to well-being, concentration, performance in workspaces and many other advantages.

Today, more than ever, people are aware of the contribution of nature to humans, particularly in workspaces, because it promotes creativity, productivity, the well-being of workers and many other advantages which make it possible to provide good performance. From the results of the questionnaire, it is evident that plants are important for people, and they can be integrated in many ways into office buildings but the implementation of actions likely to change the usual workspaces is still weak.

For application in the work environment, three integration systems have been proposed from the first of the three categories of biophilic design which are green interior spaces, green

walls and green roofs and according to the possibilities observed on the bank building, it is possible to affirm that these systems can be integrated into the building to improve the interior conditions and those users. For these changes and this integration to be possible not only in the building analyzed but also in other office buildings, it is important to understand the need that exists and to know how to respond effectively for a palpable improvement in the built environment and the city in general.

CHAPTER VI

Conclusion and Recommendations

This last chapter deals with the conclusion deduced from the various data processed in this study as well as the various recommendations.

Conclusion

The word development is often well received because it implies a change, an increase in possibilities which are likely to benefit many people whether at the urban, provincial, national level or even on a large scale such as the global level. But if development is not controlled and managed meticulously, it can cause consequences at all these levels which may be irreversible. This is the case with the development of cities which have resulted in part in multiple constructions serving several activities, which has caused a real break between humans and their natural environment. Thanks to research in certain countries, this break has been noticed and through several means such as biophilic design, this separation can be repaired at certain levels but not at all levels because to repair damage, it is first necessary to repair it. noticing and understanding are involved. Indeed, according to various research, there is an innate link between living beings, which implies that man naturally needs to be in contact, whether physical or even visual, with the elements of nature because for him it is a biological need. But built environments have created a gap between living beings and other living creatures, which is not good for humans or even for the environment. For there to be repaired, this innate need must be recognized and considered in development and through biophilic design, it is possible to try to re-establish the link. However, for a concept to be implemented effectively, it must first be understood in its full scope. Indeed, biophilic design, which is an architectural concept, aims to reestablish the link between humans and other living elements through the integration and representation of natural elements in the building. This design therefore presents itself as a strategy for reestablishing the link between living things and regenerating the natural environment.

Biophilic design is very important in buildings and more particularly in office buildings which are places in which several activities take place, and they accommodate several people for several hours which implies a large consumption of energy and workers who spend a lot of time

cut from the outside and nature. The adaptation of biophilic design in workspaces makes it possible to create a pleasant and healthy working environment which promotes the physical and mental well-being of occupants and the increase in the intellectual faculties of workers, which is a considerable advantage on productivity and the performance of the company. In office buildings the concept presents economic, social and environmental advantages for the company and for the city. But for these advantages to be profitable, it is necessary to choose the right system to adapt to the type of building. To do this, the three systems selected in the first category of biophilic design patterns present considerable potential to be considered in the design and layout of office buildings to have biophilic workspaces.

The case study chosen in this research which is a bank building located in the mining town of Kolwezi, in the Democratic Republic of Congo, is a work space which presents itself well and offers a good working environment in general but without for you might as well take into account the biophilic side, which makes it likely to be affected by several factors and this can have an effect on the work environment and on the users of the building. Indeed, it is obvious that a building can be influenced by internal and external factors which can have an impact on the atmosphere in the building. Thus, considering the climate and the environment in which the private bank building is located, it is possible to say that several factors are involved and constitute elements to be considered if an adaptation is desired for the improvement of this working environment. However, despite the various shortcomings on the biophilic level that the building presents, there is a real potential for adaptation of one of the systems or even all three systems which allow the contribution of natural elements into the building and thus transform the place into a biophilic space.

Recommendations

Biophilic design in an office space is very important on several scales and its adaptations in different work spaces really need to be taken into account. However, this adaptation presents requirements that are important for it to be effective. The building of the private bank presents considerable advantages in the adaptation of green systems such as green walls, green roof and plants in the interior space. In order to be able to put these systems into practice, it is necessary to:

- Check the type of roof the building has to see what type of green roof can be adapted and what the roof can support. Indeed, the green roof system has considerable weight and installation requirements that not all roofs can support, so it is wise to carefully check the nature of this roof and evaluate the different possibilities.
- Carefully choose the type of green wall that may be ideal for this building in relation to its construction materials. Indeed, because the building already exists and it was not built with the aim of accommodating green walls, the type of wall must be adapted to the nature of the building.
- Integrate plants with ecological requirements that are suitable for buildings and users so that there are no negative returns knowing that plants are effective and fully present advantages only in environments where they can adapt and develop. There are plants that can flourish indoors as well as outdoors and others that only thrive outdoors, so the choice of plants is important for effective integration.

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APPENDICES

Appendix 1

Questionnaire

Section 1: General Information

1. Gender

- ❑ Male
- ❑ Female

2. Age

- ❑ 18-30
- ❑ 31-45
- ❑ 46-60
- ❑ 61 and over

3. How long have you been working at the company?

- ❑ 0-1 year
- ❑ 1-5 years
- ❑ 5-10 years
- ❑ 10-20 years
- ❑ 20 years and over

4. How many days a week do you spend at work?

- ❑ 3 days
- ❑ 4 days
- ❑ 5 days
- ❑ 6 days
- ❑ 7 days

5. How much time do you spend in the office on a working day?

- ❑ Less than 6 hours
- ❑ Between 6 and 7 hours
- ❑ 8 hours
- ❑ 9 hours
- ❑ More than 9 hours

Section 2: Biophilic Design in the Office Building Results

Questions	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Is Biophilic design important?					
Is it important today to take it into account in the built environment?					
What do you think about the integration of biophilic design into the workspace?					
What do you think about the presence of natural elements in your workspace such as an aquarium, a fountain, plants?					
	Yes	I don't know	No		
Does the design of your office impact your performance?					
Is daylight important to you at work?					
Does the painting of your workplace impact your concentration?					
Is natural ventilation better than artificial?					

Section 3: Greens in the Office Building

Questions	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
What do you think about the presence of plants in the workplace?					
What do you think about integrating a green wall to the office building?					
What do you think about integrating a green roof on an office building?					
	Yes	I don’t know	No		
Are places that have plants better than places that don't?					
Are plants important for human well-being and the environment?					
Would you like to have plants in your workspace ?					
Do you think that the presence of plants in an office can have a social, economic and environmental advantage?					
Do You think that contact with nature has positive effects on your work?					

NEAR EAST UNIVERSITY

SCIENTIFIC RESEARCH ETHICS COMMITTEE

13.01.2025

Dear **HOULDA ILUNGA**

The entire study titled **„BIOPHILIC DESIGN IN THE OFFICE BUILDINGS: ANALYSIS OF A PRIVATE BANK IN KOLWEZI„** numbered NEU/SS/2025/C009 that you have submitted to the Scientific Research Ethics Committee has been evaluated, and it has been decided that there is no ethical violation in the completed study.

Prof. Dr. Aşkın KİRAZ

Head of the Scientific Research Ethics Committee

Appendix 3

Similarity Report

all thesis

ORİJİNALLİK RAPORU

%BENZERLİK ENDEKSİ	%İNTERNET KAYNAKLARI	%YAYINLAR	ÖĞRENCİ ÖDEVLERİ
9	6	6	%4

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