INTEGRATION OF GREEN STRATEGIES IN THE DESIGN OF TECH INNOVATION HUB IN MINNA, NIGER STATE

BY

NDANUSA, Abdullahi Musa
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ABSTRACT

The growing use of Information and Communications Technology (ICT) and related technology has led to the emergence of a more innovative workspaces. With changes in the manner in which people work, think and adopt the use of technology, new workspace models have arisen. As work continues to change, the organisational structures in which it is carried out is also changing. Accordingly, the energy requirement needed to run these hubs continues to reflect these changes amongst which is its contribution to the increasing level of atmospheric carbon emissions. The aim of this research is to integrate green strategies in the design of a tech innovation hub in Minna, Niger State. A descriptive research method was adopted for this study, both quantitative and qualitative data were obtained through reviewing of literature, the use of observation schedule, questionnaires, and interviews. A total of seven tech hubs were selected purposively, consisting of five local and two foreign case studies in order to compare and contrast what is obtainable locally and internationally. The questionnaires made up of open-end questions were administered to respondents within the local case studies. They comprised of professionals (architects and cost surveyors), facility managers (staff and janitors). The data collected was analysed using SPSS and the results were further presented in tables and charts. It was observed that 100% of the buildings rely on the use of non-renewable sources of power as an alternative to the national grid. Furthermore, that 100% of the buildings made use of vertical sun shading devices, while 50% of the buildings use horizontal sun shading devices. Green spaces outdoor were mostly courtyards 40%, by gardens 25% and covered porches 25%, however sit-outs had the lowest 10% of green spaces that were integrated in the design. The study concludes that across the five local case studies, there was a low-level of integration of green strategies in the buildings and the impact of these strategies do not reflect in the energy requirement of the tech innovation hubs. It is recommended that the government should enact policies that will encourage the adoption of green strategies in tech hubs in line with what is obtainable in developed countries. More also, the professionals within the built environment need to be sensitized on the benefits of adopting green strategies from design stage and construction stage to achieve rationalization of energy consumption in buildings.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Modern workspaces, their space requirements and function have changed over the past few decades. This can be attributed to economic, social and technological changes in the corporate world. The growing use of Information and Communications Technology (ICT) and related technology has led to the emergence of a more innovative workspace (Njeri, 2010). With changes in the manner in which people work, think and adopt the use of technology, new workspace models have arisen. Technological advancements continue to be a catalyst in shaping our physical work setting (Stallworth and Kleiner, 1996). Teamwork and collaboration are now of increasing importance, leading to changes in the definition, size, functionality and social significance of workspaces. Today, many young people are becoming entrepreneurs in large numbers by applying their creative energies to different fields. The information technology revolution is doggedly gaining momentum and is revolutionizing all sectors of the economy by creating new opportunities for starting businesses (Coward, 2014). There are a lot of changes occurring, such as the nature of work, the structural systems of workspaces, the nature of employees and the methods used to carry out activities, we see that the open structure and shared spaces method is gradually changing the method of architectural design. (Chen *et al.*, 2007).

Accordingly, De-Bastion (2013), defines a tech innovation hub as a nexus point for start-ups providing public or private spaces that are often equipped with Modern technology focused at advancing product and idea development. Hubs are usually made for definite clusters (such as robotics or pharmaceuticals) and are utilized by varying

factions (students, companies, start-ups). Hubs often integrate other spaces of innovation such as accelerators communities, academia, investors, technology companies and other sectors of the private nature. It can be a set of buildings or a specific building where start-ups can rent spaces and corroborate ideas and share facilities. These hubs aid in active knowledge diffusion between researchers and business experts. It can also serve as a meeting ground between industry, government and representatives of academia and tech entrepreneurs. Spaces of innovation are indicators of physical economic, demographic, and cultural forces. The ever-metamorphosing nature of scientific innovation also metamorphoses workspaces into flexible and open spaces that enable varying professions and disciplines to interact seamlessly (Friederici, 2014).

The challenges arising from the impact of climate change has increased the need to stimulate a more sustainable approach in the development of the non-green industries (Bribian *et al*., 2011). This vital issue has resulted in major stakeholders proffering possible solution on how to restore and protect the ecological system. More also, as world population continues to increase, and economies grow bigger, apparently so is the strain on the available natural resources. Yudelson (2009), asserted that worldwide, the building industry accounts for the consumption of approximately 60% of the earth's raw materials. The consumption of this non-renewable mineral resources is detrimental to the environment, subsequently causing degradation (Wadel, 2009).

1.2 Statement of the Research Problem

Tech innovation hubs often have large carbon footprints due to their huge energy requirement which contributes to the increasing level of atmospheric carbon emissions

(Gil-Mastalerczyk, 2016). Consequently, there is a general consensus towards halting the rise in greenhouse gas emissions especially in urban centres. Furthermore, the world population is forecasted to reach 5 billion by 2030 according to United Nations Population Fund (UNFPA, 2013). A lot of this urbanization will happen in Asia and Africa, causing large economic, environmental, and social changes. Hence the need to adopt a more sustainable approach by incorporating green strategies in tech hubs so as to proffer lasting solutions to greenhouse gas emissions which in the long run will not only endanger our planet but also its habitant.

1.3 Aim of the Study

The aim of the research is to integrate green strategies in the design of a tech innovation hub in Minna, Niger state.

1.4 Objectives of the Study

The objectives of the study are to:

i. Assess the evolution of local and international tech innovation hubs
ii. Identify the existing green strategies that have been integrated in tech innovation hubs.
iii. Design a tech innovation hub that is focused on sustainability within the frameworks of environment, social and economic impact.

1.5 Justification for the Study

With significant growth over the years in the creative economy and information technology in Nigeria, private individuals and even the government are investing heavily in the development of tech innovation hubs. There has also been an increase in

the design of co-working spaces globally, which embody creative values and support innovation. This calls for a need to understand how these workspaces operate, their impact on the environment and the users of this workspace. Consequently, integrating green strategies in the design of a tech innovation hub will not only help to reduce the negative impact of carbon emissions these hubs have on the environment, but also help to proffer future designers with pathways on how to adopt these green strategies.

1.6 Scope of the Study

This thesis will focus on making provisions for the facilities required in a proposed tech innovation hub. The facilities provided will be integrated with green design elements in order to promote sustainability and reduce the negative impact on the environment. The facilities to be provided include auditorium, boardrooms, collaboration and innovation spaces, research and development labs, fabrication labs, data centres.

1.7 Study Area

The city of Minna is situated in Nigeria in the middle belt region, it is the capital city of Niger state and has 3 major ethnic groups: Gwari, Hausa and Nupe. Additionally, it has a population of over 300,000 people as of 2007, the city can be seen in Figure 1.1. It is linked to the nearby states and cities by road and the popular river Niger. It is connected to Abuja by a major federal highway that spans about 150km and also uses the rail lines to stay connected to neighbouring cities like both Ibadan and Lagos in the south and Kano in the north.

It is home to several learning centres such as: Niger state school of health, The Federal University of Technology, Niger state university of Education and others. It also has

several secondary schools such as Police secondary school, FEMA Schools, Hilltop Model School, Zarumai model school, Mypa schools, Kowa Schools, Himma international school and many more. Therefore it is a suitable location for a Tech hub as it has not only the land for the structure but a close proximity to the Nation's capital and an industrious youth population.

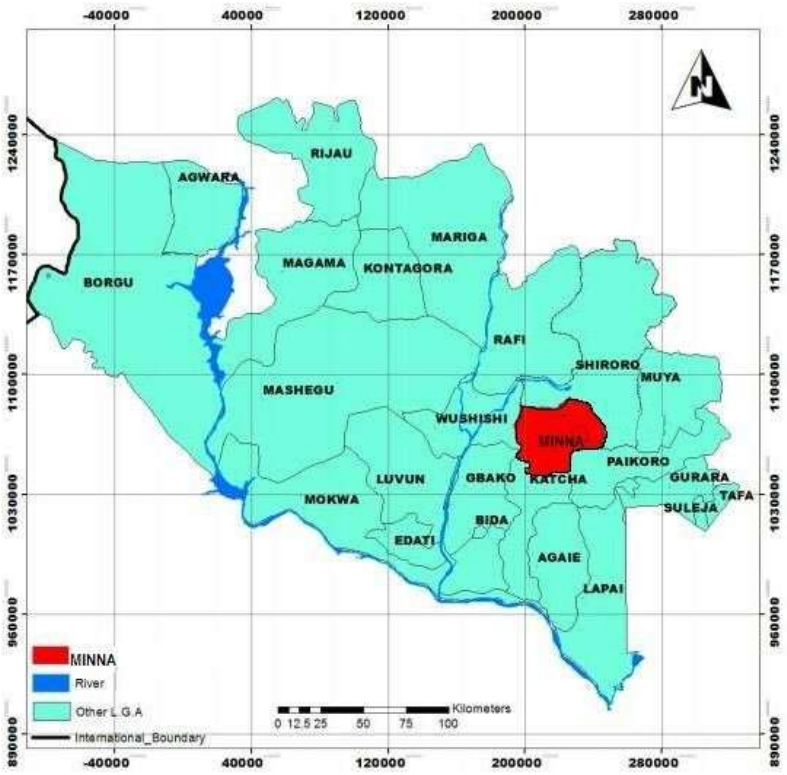


Figure 1.1: Niger state showing Minna

Source: Veal, (2006)

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 The Ancient Greek Research Workspaces

In ancient times, the early places of research understood the importance of the inclusion of natural elements in a bid to foster places for thinking. An example is Plato's Academy, which was initiated in 387 or 388 BC, in a public garden used for gymnastics and was given to Athens by Hecademus or Academus. It was located at the outskirts, about a kilometre, away from the main city. A barrier wall was constructed to surround it, and the surrounding areas which contained the sepulchres of some important Athenians, temples, and statues. It used some architectural elements such as high walls and extensive spaces above to generate creative thinking and so spaces like this should be considered where there is a need for creative thinking (Stefan, 2006).

2.1.1 The rise of the 19th century workspace (1900 -1990)

From 1900 to 1950 economic progress and the introduction of modular ceiling, reinforced concrete and modular systems, produced higher quantities of lettable work space and the making of a number of commercial opportunities. Additionally, the advent of the Industrial revolution signified that people relocated to a dominant locality as the importance moved from agriculture produce to manufacturing. The move of workforces to urban areas caused urban centres to become more compactly populated, making the need for inner city commercial structures and the need for sufficient transportation. Workplace environments transformed considerably between 1950 and 1970 during which the development of corporate culture was promoted, resulting in

allocation of organizational space in the office buildings to be made by worker's pecking order (Stefan, 2006).

The workplace environments were planned to use the open plan concept, which has entry level workers placed together, based on their department and function. High level workers such supervisors or managers were gifted the notable areas of the working environment, with the coveted window views. This type of plan based on workers hierarchy allowed the employers to supervise their workers from the comfort of their own offices as there was a clear line of sight because of the architecture of open planning. However, this type of design was later discarded in the design of Tech-hub workspaces (Wheeler, 2015).

Modular systems which provided greater flexibility and efficiency were brought about by the need for more independently manned stations in the 1970s to 1990s which was instigated because of the conversion of more work processes to being mechanised and operated by technology (Oltra and Saint, 2009).

2.1.2 The Contemporary Research Workspace: 1990 – present

The present office settings and way back to the 1990s experienced a change in the use of wireless technology. This period of time saw the drivers of designing workplaces change to more sustainable approaches and also flexibility to varying needs of individuals and companies. The advent of technology has created the need for new spaces within the working environment and has fostered the creation of several hi-tech phrases that are common in workspaces daily such as webinars, downsizing and the use of smart devices (Sloane, 2011).

2.2 The Rise of Innovation Hubs in Africa

In the last few years, the African continent has experienced a considerable rise in technological entrepreneurship. A lot of faith has been placed on grooming indigenes digital economy with the hope that it will serve as a catalyst for socio-economic development. As asserted by Saraswati (2014), that governments within the region are investing and building cities for tech entrepreneurs. Tech hubs on the continent has interestingly attracted a lot of attention from individuals, cooperate organizations and researchers alike. One amongst many is the recent visit of Mark Zuckerberg, the founder & CEO of Facebook to Kenyan and Nigerian start-up innovation hubs. The start-up ecosystem in Sub-Saharan Africa particularly has become more competitive in recent times. The theme "Made in Africa'' software has already been used in many projects, such as M-Pesa, before the initial visit to Nairobi of Mark Zuckerberg. The mobile and web-based start-up, launched in 2007 by Safaricom, enables its users pay for services and products and to make financial transactions on their phones without the need for a bank account. The M-Pesa now stands for technological innovation from Africa, as it is used in Kenya and its neighbouring countries.

In the past nobody in the business world would have connected sub-Saharan Africa with technological innovation, yet today's 'Silicon Savannah' is used frequently in and around Nairobi to characterize the booming IT sector. The capital of Kenya, Nairobi, has been the focus of the Silicon Savannah since the launch of Innovation Hubs (iHub) as a space for open innovation for start-ups in 2010. IHubs in particular were given great importance, so that they could be seen as a landmark for the establishment of iHubs in sub-Saharan Africa and beyond.

So also, researchers have turned the spotlight on this area, with Gathege and Moraa (2013), report comparatively assessing various variables like size, tenants, age, funding, and partnership and identifying the common features. However, researchers have suggested the need to further broaden the scope of research on subject matter, as so far, only minimal descriptions exist, expounding on the precise nature of IHubs and describing their main supporting infrastructure (Friederici, 2014). Nevertheless, some authors have highlighted the gaps in literature to be that tech hubs have been barely explored from the start-ups' point of view. No significant number of researches have been undertaken to clarify the precise needs of start-ups working in IHubs to further draw assumptions about the essential support systems required within the tech hubs. Majority of the earlier studies do not take into account how start-ups work in a complex environment but with a rather one-dimensional perspective (Kelly and Firestone, 2016).

2.3 Sustainable or Green Architecture in Workspaces

The idea backing green or sustainable architecture is the style, science, theory of designing and construction buildings with sustainable principles. Also, Green architecture focuses on minimizing the amount of resources consumed during the creation and utilization of a building with the aim of curtailing any potential negative impacts on the environment via toxic emissions or pollution of its several components (Ragheb *et al.,* 2015). Green, Sustainable or Eco-friendly Architecture as used interchangeably by different authors to refer to the same concept. Professionals in the Architecture, Engineering and construction industry have come across the term sustainability, in one way or the other. The construction industry offers a distinctive challenge to sustainability (Mohammadjavad *et al*., 2014). Construction projects generally require large number of materials, energy and water resources and it produces

waste in large amount. Although a number of definitions exist for the term sustainability in Architectural framework, it still remains vague due to lack of details on how to apply its principles in practice (Sassi, 2006). In an attempt to comprehend the meaning of sustainability and apply its principles into practice, definitions according to different authors are identified.

Furthermore, Attaman (2010) asserted that the term "green" is one the most extensively used in recent times but unfortunately; it is poorly defined in architecture. He went on to define Green Architecture as the design and construction of buildings that are technologically, materially, ecologically, and environmentally stable. Subsequently it was stated that within the context of sustainable architecture, stability is narrowed into, sustainability of technology and materials, sustainability of resources and the environment. More also, Sinha *et al*., (2012) quoted the Environmental Protection Agency (EPA) definition of green architecture as the principle of erecting buildings utilizing processes that are sustainable and efficient all through the life cycle of a building which spans from design to demolition. According to Roy (2008), green architecture, or Sustainable architecture is a way of design and construction of buildings that reduces detrimental effects on the environment and people.

2.3.1 Historical overview of green architecture

The history of green architecture is linked with the history of humankind because from the inception of humanity (hominids), an interaction between man, the environment and ecology were established (Attaman, 2010). Along the evolutionary line of humans which is categorized into Homo habilis and Homo erectus four million years ago. The first homo habilis were capable of making stone tools that could be used to separate

meat from animal carcasses. However, the Homo erectus with a more advanced brain was more skilful, innovative and could adapt more seamlessly with the environment. The possibility of making and controlling fire grave invented by the Homo erectus gave them the power to migrate to other areas and adapt to different climatic conditions by making cloths and shelter (Cullen, 2010). The Ice Age was bitterly cold, but they survived and at some point, migrated to areas that were not previously inhabited. At this time, human beings developed improved composite tools and weapons which were lighter and more efficient in providing shelter. The increase in population and changes in the climatic conditions gave rise to the need for exploring new that already developed strategies to survive under the harsh conditions. Plants and animals began to colonize larger areas around the earth including areas that were previously not habitable in Africa, Europe and America and this gave rise to a steady growth in the population of human beings. Dependence on hunter tribe groups on different cultivated plants became imperative and this led to the formation of settlements and farming communities.

The paradigm shifts from nomadic to agrarian societies where human beings modified the environment to suit their settlement brought about changes in the ecology. These new settlements required resources to meet different requirements ranging from provision of shelter to heating, and cooking of food. To meet these requirements, deforestation started and this consequently caused soil erosion and other ecological problems surfaced around the areas that were occupied (Ponting, 2007). The ecological destruction which caused major environmental changes gave rise to environmental protection awareness in the 18^{th} century. Most of the early reactions were short accounts and local environmental policies were formed.

The mid-eighteenth century witnessed an industrial revolution which gave rise to technological advancements leading to a radical departure from hand to machines. New building materials such as steel and iron emerged and other sources of energy such as steam engine, coal, petroleum and electricity were developed (Attaman, 2010). However, this new technology increased natural resource exploitation, spurred massive population growth within the urban settlements. Consequently, the need to protect the increasing population and nature became a serious and urgent issue. After the World War II in the early 1900s, environmental movements began to emerge with intense activities of how to protect nature and mankind from extinction. In as much as the intent was the same, the movements became more global and complex during this period. Limited resources, advancement in new technologies and materials, new scientific discoveries, global pollution and economic disparities, increasing ecological stress became the new point of the environmental movement. The World Commission on Environment and Development in 1987 organized a summit and came up with the definition of sustainability as the ability of the present generation to meet their needs without compromising the ability of future generations to meet their own needs. Architecture was identified as a direct response to the emergence of this movement. A new approach to designing buildings to reduce negative environmental impacts was required and this gave rise to the term green architecture which also refers to sustainable architecture or environmentally friendly architecture. Some architectural and construction establishments commenced rating and certifications to foster international best practices in architecture (Damati, 2013).

2.3.2 Concept of sustainability in architecture

According to Osama *et al.* (2017) explained the word sustainability as being utilized with its present purpose and what can be sustained in the near future. The concept of sustainability in architecture is not solely to make buildings that will solely stay for a long time because buildings of several years are not consistent with the needs of the current time. Architecture can be deemed sustainable if it is receptive to the requirements of the present. In new matters of sustainable architecture, it is endeavoured to decrease the undesirable effects of novel architecture on the surrounding environment and also energy is utilized effectively through the use of materials harmonious with the environment, especially the climatic conditions of the site. Sustainable buildings are known as structures that have the least harmful effects on natural and artificial environment. Sustainable architecture has considerations for the lifecycle of a building, maintaining an environment with high quality, good performance and the future (Damati, 2013).

2.3.3 The strategies and principles of green design

Literally, a principle is regarded as a fundamental proposition or assumption that guides the basic foundation for a system of behaviour, belief or chain of reasoning. Whereas a strategy connotes a plan of action properly defined to achieve a particular aim. Similarly, Green design principles are fundamental prepositions of sustainable development that guide designers to create buildings of high performance with less negative impact on the environment (Gil-Mastalerczyk, 2016), they can be seen in Figure 2.1. The principles entail an integrated and comprehensive approach throughout the building's phases from construction, operation, maintenance and decommissioning. Each of the design principle entails a set of unique strategies that can be disaggregated,

analysed, and employed by architects to reduce the environmental impacts buildings they design.

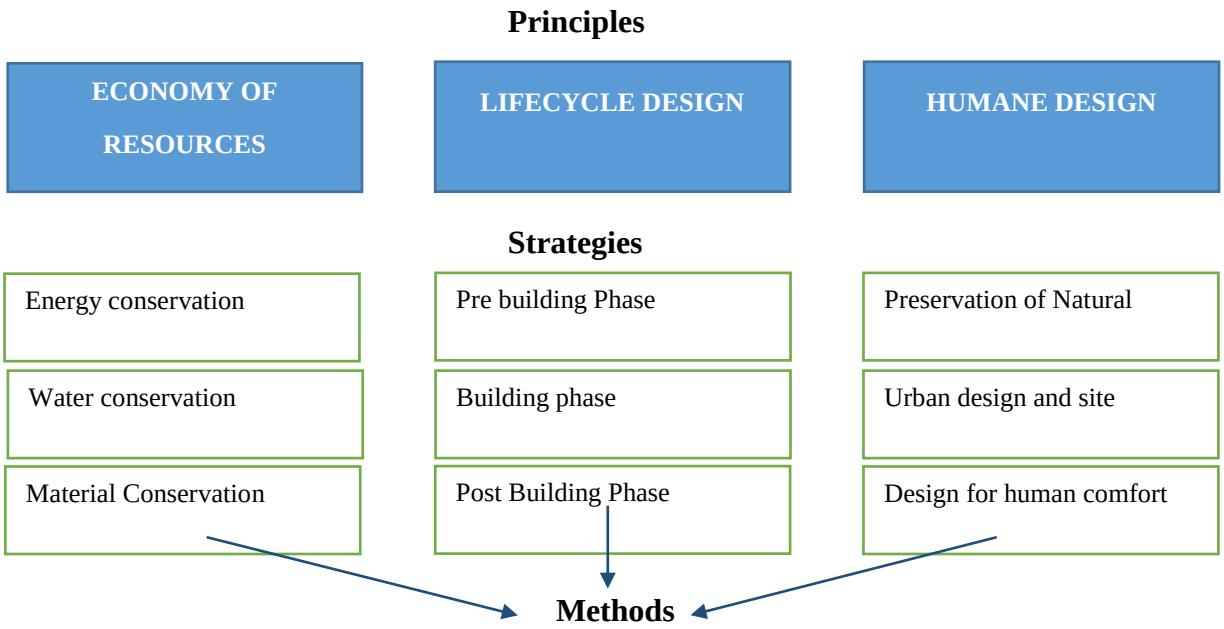


Figure 2.1: Sustainable design principles

Source: Kim (1998)

For designers to meet the objective of co-occurrence, Kim (1998), proposes human design, lifecycle design and economy of resources as the three key concepts in sustainable architecture. Economy of resources is concisely about reducing, recycling,

and reusing of the environmental resources employed in buildings. Life cycle design gives a framework for analysing the entire building timeline and its negative effect on the environment. Lastly, humane design is based on human interaction with nature. Figure 2.1 shows the sustainable design principles proposed by (Kim, 1998). However, more recently a multi-disciplinary approach has been suggested by Asif *et al.,* (2007) for adoption in the construction industry. This covers several subjects such as: waste reduction, pollution control, energy saving, emissions control, and effective use of materials. To make a good advantage using environment-friendly construction practices, the whole life cycle of buildings should be the principle used to carry out building operations.

2.4 Resources Conservation during Building Construction

The conservation of resources highlights the need to achieving more with less. It entails the management of non-renewable resources to offer the supreme profit for the present generations while sustaining the ability to meet the requirements of future generations (Wilson *et al.,* 1998). For a building to be constructed, natural and manufactured resources flow continuously in and out during the entire process. The flow of these materials begins from the time of construction and continues all through the building lifecycle in order to foster an environment that sustains human activities (Kim, 1998).

As cited by Graham (2003), that the construction industry is a key user of nature's resources, and so many of the ingenuities followed to make sustainable structures focus on growing the effectiveness of resource use. Therefore, if Natures resources are not carefully managed in the near future the construction industry might be non-existent.

2.4.1 Conservation of energy to achieve efficiency

Energy use and management is a key topic in environmental use. Its use is unavoidable in any actively functional society as structures are the leading consumers of energy. According to a report by Sustainable Architecture and Building Design (SABD, 2005). Sustainable building designs are beneficial in terms of economy (cost savings), social (poverty reduction in fuel), and the ecosystems (Reduction in resource exploitation and emission of greenhouse gases). Sustainable building design with respect to energy efficiency aims at enabling inhabitants of buildings to maintain their quality of life with minimal emissions (Sassi, 2006). The most direct and sort after solution to the use of fossil fuel is to adopt renewable energy.

Nevertheless, the economic and technical challenges of employing renewable energy sources by far outweigh the possibilities. According to Osama, *et al.* (2017), the comparatively high cost of energy resource extraction, transmission and distribution issues significantly influenced the concept of improving its efficiency and conservation worldwide. There are several strategies that aid in the conservation of energy and they include;

2.4.1.1.1 Passive solar design in buildings

Passive design involves using the architectural and structural elements to minimize the energy consumption of a building. These elements take cognizance of the environment to carefully optimize the building's envelope with the climatic conditions (Ragheb *et al.*, 2015). Passive solar design therefore means harnessing the energy of the sun for the cooling and heating of spaces within a building. The structure and some elements use the innate abilities of the materials used in construction to utilize the suns energy. To

achieve this, the following passive solar features are utilized for energy efficiency in buildings: Thermal insulation, the building orientation, shape and form, site analysis and planning, natural day lighting and ventilation, use of landscape to reduce heat island effect, thermal storage of roof and walls and efficient (Graham, 2003). Some passive design strategies adopted in a building are shown in Figure 2.2

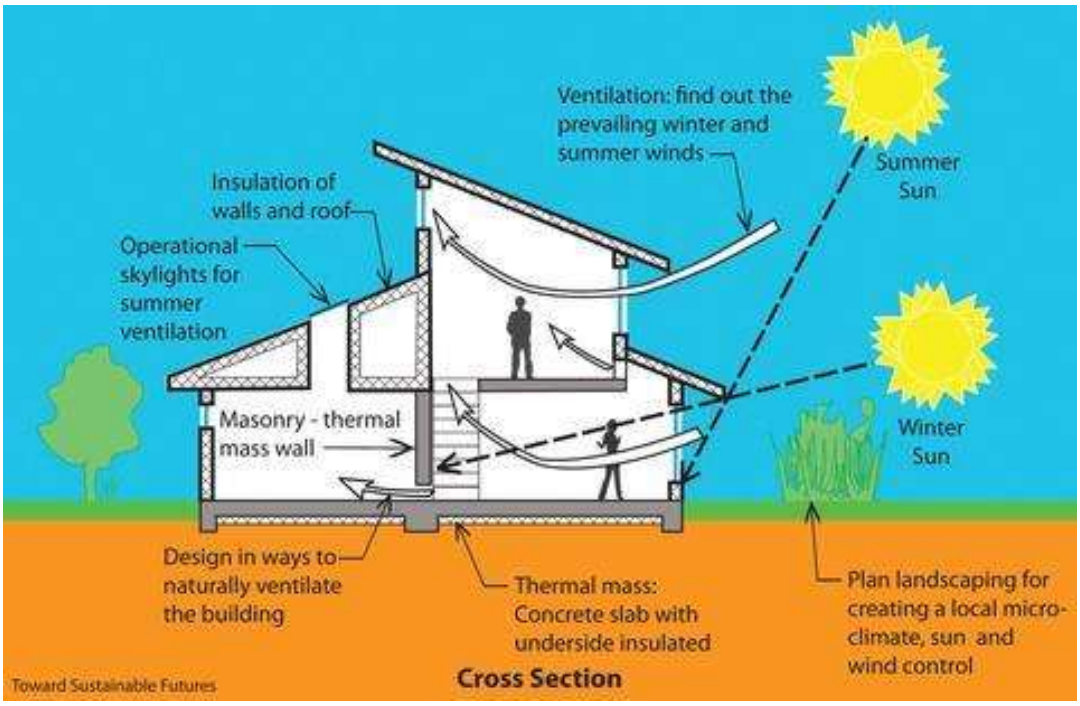


Figure 2.2: Passive design strategies

Source : (Ragheb *et al.*, 2015)

2.4.1.2 Choice of materials and construction methods

It notable that the choice of building materials selected affects the energy use of a structure via reduction of heat loss or gain, thereby dropping air-conditioning use. The choice of materials having low embodied energy will aids in the reduction of energy used in the collection, sorting, production, and courier of materials. (Dimoudi and Tompa, 2008). For example, aluminium has a high embodied energy because of the

huge level of electricity used to gather the raw material. When constructing low energy buildings this should be considered and the lifecycle assessment should be used.

According to SABD (2005), the following strategies should be employed to reduce embodied energy without reducing the efficiency of building materials; Re-use of existing structures where possible, design of buildings with long life and ease of maintenance while adapting to emerging trends, use local building materials with low energy and site design with significant reduction in pavement. Concrete, brick and timber are the construction materials having the lowest embodied energy and are frequently used in large amounts as shown in Figure 2.3.

Figure 2.3: Hub Accra building in Osu neighbourhood

Source: Nicolas (2014)

Naturally occurring materials usually have low toxic levels and embodied energy than their manmade counterparts (Godfaurd *et al.*, 2005). Natural materials need less refining and so contribute fewer negative effects to the ecosystem and most of them have been

tagged as been renewable, therefore the incorporation of these materials into structures makes for an overall sustainable output. Additionally, when locally available materials are used in construction, they reduce negative effects by an overall reduction in transportation thus reducing pollution and are even adept to the environment because they are sourced from it (Kim, 1998).

2.4.1.3.1 Water conservation and efficiency in buildings

The reduction of available water resource has been stirred by the growing development of economy globally and has thus become a worldwide concern. The United Nations World Water Development Report (WWDR, 2013) cemented this by stating that there is a growing scarcity of water for all the necessary human uses and it will eventually cumulate in a water crisis. In the same manner in which water is an essential commodity needed for survival on earth so also does a building requires water in large quantities to serve occupants for different purposes such as cooking, drinking, washing of cloths and cleaning. Accordingly, Oliveira *et al.*, (2009) noticed that in building design and construction water conservation is often overlooked. They however believe that in planning for the usage of water in a structure water savings can be achieved which is of utmost priority now. In providing solutions for water related issues in the environment, the first step is to reduce the amount of water used which will in turn reduce wastewater. The following strategies are usually employed to reduce the water footprint of buildings (Mohammadjavad *et al.,* 2014).

The utilizing of water efficient plumbing fixtures can be adopted. This includes the use of, waterless urinals, ultra-low flow toilets and urinals, low-flow and censored sinks, low-flow showerheads, and water-efficient dishwashers and washing machines, to

minimize wastewater. Additionally, the use of redistribution and circulating systems which aid hot water distribution efficiency. To accomplish water protection and conservation a dual plumbing system is a viable system that is designed re-use water for flushing toilet flushing for other functions through the use.

Water recycling can also be used, it is a process in which water is captured, stored, treated (if required) and reused. The two basic methods are rain water harvesting and grey water recycling from households. A typical grey water harvesting strategy adopted in a residential building is shown in Figure 2.4.

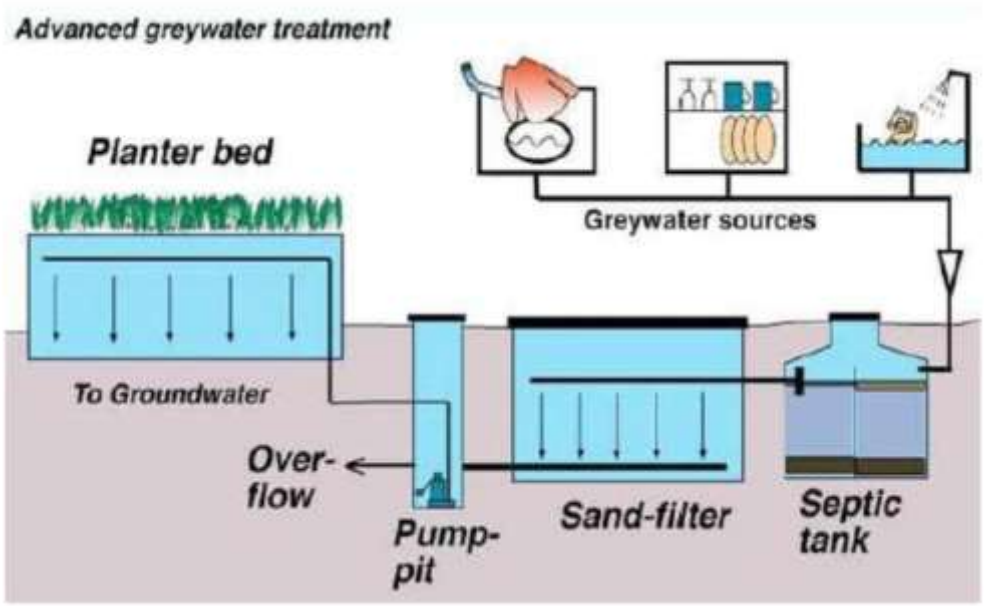


Figure 2.4 Grey water recycling/harvesting approach

Source: Mohammadjavad *et al*., (2014).

Landscaping generally refers to the modification of the visual features of land with the aim of creating a beautiful landscape. Landscapes create serenity, harmony and pleasure within an outdoor space. Some are water saving and require high maintenance.

Xeriscaping is a method of landscaping which is used to create eye-catching and water efficient landscapes. They focus on soil improvement, turf areas, use of mulches, efficient irrigation and low water demand plants.

2.4.2 Materials/resources conservation in construction

During the construction stage of buildings, an influx of buildings materials usually occurs and this generates significant waste. Also, after construction of the building, a low amount of supply of materials remains primarily for maintenance, renovation and replacement activities (Kim, 1998). All these materials at different phases are output and usually require recycling or disposal. These materials have a copious impact on buildings ranging from cost, constructability and environmental impacts. In recent times, substantial research has revealed a better understanding of the extraction, processing and management of materials reduce negative impact on human beings and the environment (Sassi, 2006). The strategies for conservation of resources include; Use of recyclable building materials, use of natural and nontoxic materials, proper solid and liquid waste management, rehabilitation of existing buildings and avoidance of resource depletion materials. Features of sustainable building materials are shown in Figure 2.5.

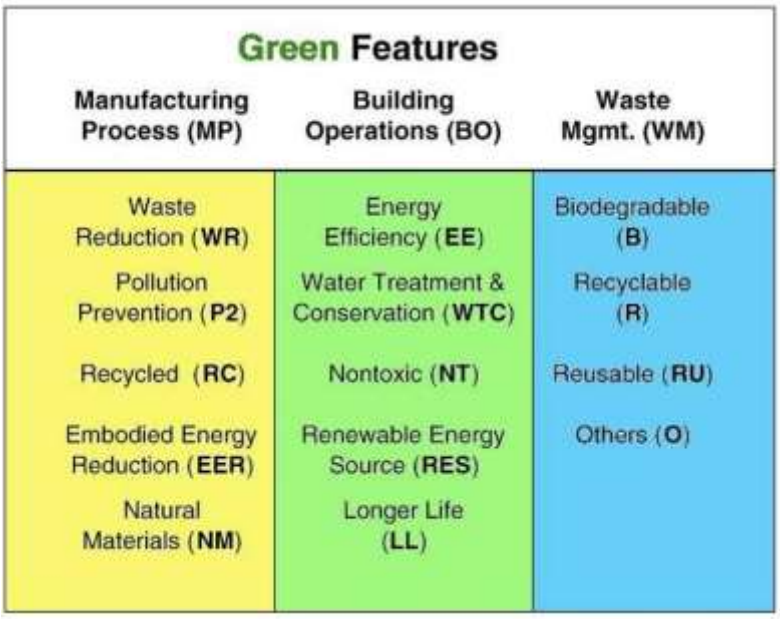


Figure 2.5: Green features of sustainable building materials.

Source: SABD (2005)

2.5 Life Cycle Design

Conventionally, the building life is made up of a linear process which includes four phases namely; Design, Construction, Operation and maintenance and Demolition. Consequently, the process does not ameliorate negative environmental impacts of buildings or the management of waste (Kim, 1998). Life cycle design is a cradle to grave principle of architecture with strategies which recognize the environmental impact of life cycle of architecture processes from design, construction to nature. The concept is premised on the fact that a material transforms from one useful stage to another through a continuous useful life cycle. The life cycle of a building is classified into three phases that are connected without boundaries namely; pre building phase, building phase and post building phase. Figure 2.6 shows the life cycle of a sustainable building.

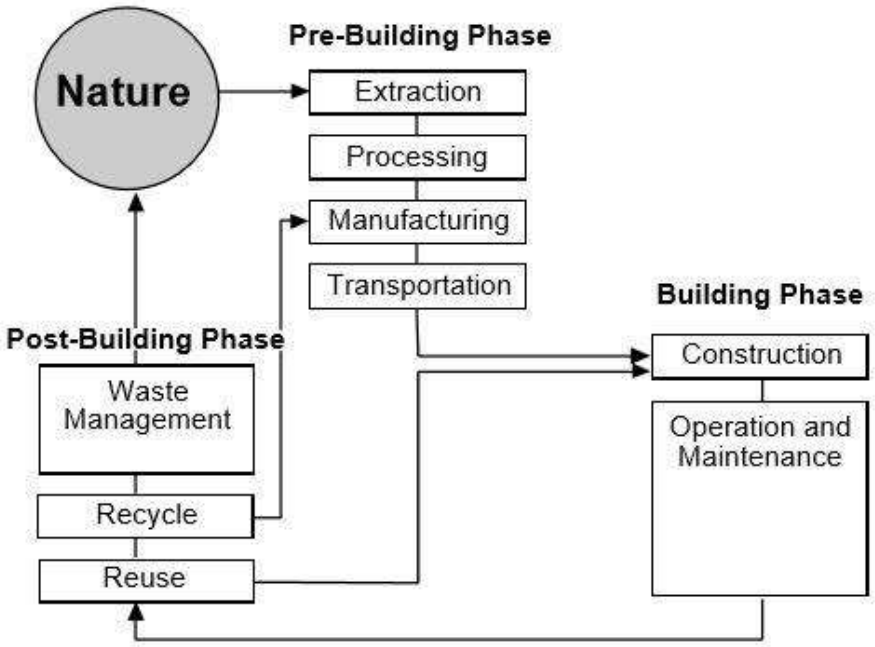


Figure 2.6: The sustainable building life cycle

Source: Kim (1998**)**

2.5.1 Pre-building phase

The pre building phase of project involves site assessment and selection, design of the building, analysis and processing of the materials to be used during the building phase. With regards to sustainability, the environmental impacts of the building are analysed at this point, the impact of landscaping, the most suitable orientation and materials to be used. The process of extracting and processing building materials has consequences on the environment; deforestation as a result of cutting down trees, mining of mining resources such as iron of steel, bauxite for aluminium, sand, gravel and limestone for concrete, pollution as a result of transporting the materials depending on the distance to the site. The following sustainable strategies are employed during the pre-building phase (Sheweka and Magdy, 2011).

2.5.1.1 The use of sustainable building materials

Generally, green building materials (GBMs) are classified based on their impact on the environment over the life duration of the product. The essence of using GBMs is achieve reduced maintenance, cost of maintenance and energy conservation in order to improve the wellbeing and productivity. In order to achieve sustainability, the choice of materials to be used should be influenced by the following factors. Considerations should be given to minimizing the amount of energy consumed by the material, high recyclability, durableness, rapid renewable materials, low toxicity levels, reusable or recyclable, and local production (Cullen, 2010).

The common material more frequently seen as sustainable are clay sand, straw. When water is added the resultant is a cob or adobe (clay blocks). Other materials commonly used in natural building are stone, straw, bamboo, rice -husks and wood (cordwood or timber frame/post-and-beam (Woolley, 2006). The process of extracting and processing materials for building construction requires energy and has significant negative environmental effects. On this note, the architect must have a good understanding of the local and global ramifications of the building's materials specified to be able to use materials that do not harm the eco system.

Adopting building materials that are recyclable significantly reduces waste. The recyclability of building materials enhances preservation of embodied energy that would otherwise be wasted. Virgin natural resources that would normally be consumed are also preserved when building materials are recycled. A good number of building materials, emphatically steel is easily recycled, eliminating the need for more production and the wastes that come with it (Cullen, 2010).

The consumption of raw materials required in buildings is significantly reduced when durable building materials are used. These building materials also require less maintenance thus increasing their sustainability index. This means that building users have minimal contact with irritants found in the materials during their installations and maintenance (Cullen, 2010).

2.5.2 Building phase

The building phase is a stage of a building's life cycle when the building is constructed and operated by occupants. In view of sustainability, the construction and operation processes are analysed and methods to reduce resource consumption and negative environmental impact. Also, the long-term effects on human beings and nature is taken into cognisance. The following methods associated with building phase are adopted in order to harmonize human beings and nature (Nicolas, 2014).

2.5.2.1 Waste management in buildings

Waste management refers to activities that are required to manage waste from inception to final disposal to minimize the adverse effects on the environment. During the building phase of a life cycle, solid and liquid waste is generated from activities of occupants. Sustainable waste management strategies entail conversation of waster to resources and efficient disposal when reusability is impossible. The hierarchy of waste management during the life cycle of a building is shown in Figure 2.7.

Figure 2.7: Waste management hierarchy

Source: Damati (2013)

2.5.2.2 Minimize the site impact

Site plan is a landscape architectural plan shows the full extent of a proposed site development. Sustainability of site plan helps to connect people with the ecosystem to ensure harmony. Excavations for new buildings on any site should not alter flow of ground water, buildings should respect existing site conditions and trees should only be cut down when necessary (Wheeler, 2015).

2.5.2.3 Employ nontoxic materials in construction

Nontoxic building materials are natural materials that are devoid of glues, coatings or chemicals that can cause emission of toxic gases. The use of materials that are nontoxic is essential maintaining the health of users, who practically spend 75% of their total time in buildings (Wheeler, 2015).

2.5.3 Post-building phase

The post building phase of a building's life cycle begins when the useful phase of a building. During this stage, the materials of the building become waste or are reused as resources for other buildings. Sustainability at this phase is focused on reducing waste in construction by carefully recycling and reusing these materials for other buildings. It is the duty of the designer to critically analyse the environmental consequences of buildings that have outlive their usefulness (Kim, 1998). At this point, strategies adopted are reuse, recycling of components and disposal. The disposal poses environmental threats as a result of landfill dumping, incineration which contributes a quota the already existing waste stream of the environment.

2.5.3.1 Reuse the building components and recyclable materials

The consequences of embodied energy of a building are always considered in sustainable architecture. The embodied energy as well as the energy required during construction is of great concern. In cases where reuse of building components is possible, a lot of energy is conserved. Building components such as windows, doors, bricks, and interior fixtures are mostly reused. Recycling building materials from a building is usually difficult due to the technicalities required in sorting substances. Materials, like glass and aluminium, must be foraged from the building manually. Steel can be easily be removed from building rubble by magnets and concrete can be crushed and used as aggregate in new mixes.

2.5.3.2 Reuse existing buildings and infrastructure

The construction of new suburbs from virgin land and with new materials affects the ecosystem. Also, providing new buildings and infrastructure requires large capital. Sustainable development advocated the use of abandoned existing infrastructure for new

spatial requirement. Figure 2.8 shows the sustainable methods that are adopted during the life cycle of a building.

Figure 2.8: Sustainability methods during the building life cycle.

Source: Kim (1998)

2.6 Humane Design

The third but vital principle of sustainable architecture is humane design. The economy of resources and life cycle design principles focus on efficiency and conservation. Humane design however is more concerned with the liveability and coexistence of all constituents of the ecology including wildlife and plants. This principle emerged as a result of the humanitarian and altruistic goal of respecting the life and dignity of fellow living organisms (Wheeler, 2015). Further examination reveals that this principle is deeply rooted in the need to preserve the chain elements of the ecosystems that allow human survival.

2.6.1 Design for comfort

According to Wheeler (2015) human beings spend 75% of their time indoors. Designers and contractors of buildings often consider bodily comfort when creating living spaces. Physical comfort enhances the effectiveness, satisfaction and psychological wellbeing of occupants. During the design and development of buildings, and to ensure comfort of occupant's designers lay emphasis on the thermal comfort of buildings. Thermal comfort refers to the quality of the physical indoor environment with relation to the health and wellbeing of occupants. The design lays emphasis on thermal comfort, natural day lighting, air quality and ventilation, noise control, visual quality and use of nontoxic building materials.

2.6.2 Preservation of natural conditions

The existing topographical conditions of the site should be preserved as much as possible. Radical terraforming has devastating effect on the environment as it's usually very expensive. Also, alteration of topographical conditions affects the drainage pattern of the site. Building sites that do not require excavation below the local water level should be selected more often. Wildlife and vegetation on the locality should be recognized as part of the site (Wheeler, 2015).

2.6.3 Sustainable urban design and site planning

Site plans and urban designs apply sustainability principles on a larger scale than singular structures. These methods entail an integration of public transport into the design process, minimization of vehicular access while maximizing pedestrian movement and mixed used development. This provides a greater sense of community than conventional suburbs. The humane design strategies are highlighted in Figure 2.9.

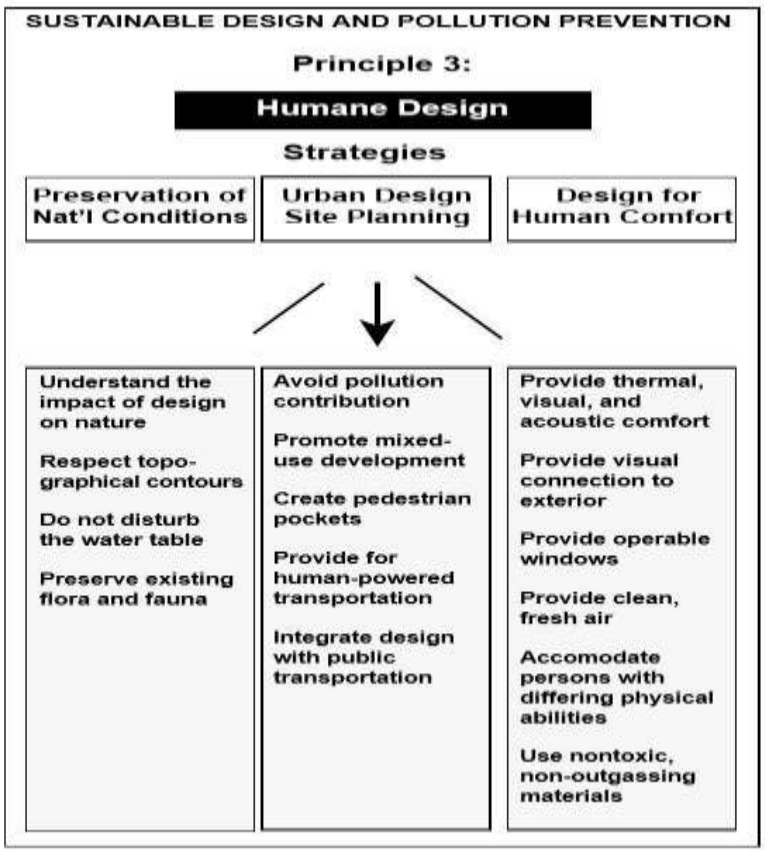


Figure 2.9: Humane design strategies

Source: Kim (1998)

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

3.1 Research Method

A research is regarded as a systematic inquiry or investigation in order to gain knowledge and understating of a phenomenon. More also, the steps, manner or ways in which a research is carried out is as important as the result itself (Creswell, 2012). This section discusses the methodological approach adopted from the array of methods utilized by different authors in the literature reviewed. This was done in line with the aim and objectives of the study with regards to how tech hubs have integrated green features in their design.

A descriptive survey method was employed in carrying out this research. The study is descriptive in nature as it is concerned with identifying, interpreting and describing what already exists. A total of seven tech hubs cases studies consisting of five local (5) and two (2) foreign were considered in order to compare and contrast what is obtainable locally and internationally. Hence, data was collected from different sources which were used for this study.

3.2 Data Type and Sources

Several means were employed to collect data in the course of this research. Yin (2009) outlines sources frequently used for case study investigation to include; documentation, file documents, surveys, observing directly, assessment of participants, and artefacts. These sources are classified into primary and secondary data.

3.2.1 Primary data

The data used for this research was gathered through the use of observation schedule, oral interview and a structured questionnaire. Green design features were assessed in existing tech hubs. This was followed by examining the variables of interest to this study. These include; location and orientation of the building, passive solar energy use, ventilation systems, the use of renewable building material, water harvesting and recycling.

3.2.2 Secondary data

Secondary source provides a second-hand data from sources such as existing literature, such as public strategy documents, Journals, books, published and unpublished theses, relating to how green design features can or has been integrated into buildings. These highlights the strides made at integrating green strategies both locally and on the global scene (Osama *et al*., 2017).

3.3 The Instruments of Data Collection

Relevant information was obtained through the use of observation schedule, oral interview and questionnaires. The questionnaire is made up of open-ended questions which allows respondent to make comments and replies where necessary. The respondents are categorised into professionals (architects and cost surveyors), facility managers (cleaners and staff). The visual survey was carried out to assess the variables of the study that were generated in line with the research aim and objectives.

3.4 Criteria for Case Study Selection

The criteria for inclusion of case studies was based on capacity of the building with regards to the number of work stations provided for use and the typology of the building. These two factors influenced the samples that were selected. A sample can be regarded as a subset or part of a population from which it is derived. Case studies in quantitative research are picked similarly to how samples are selected, generally there are chosen purposively (Veal, 2006). This highlights the reason case trials are recognized due to the intrinsic nature that allows investigations to be carried out as desired (Oluigbo, 2010).

3.5 The Study Population and Sample Size

A total of five (5) tech hubs were studied in Nigeria which includes; five tech hubs in representing 50% of sample size of 10 buildings as obtained from Morgan's table of samples. The five (5) innovation hub that were studied are; Aiivon Innovation Hub (Aiivon Hub), Ventures Park, Young Innovators of Nigeria (YIN Hub), Digital Development Hub (DDHub), Enspire Incubators Program (Enspire Hub) all located in Abuja, Nigeria. The elements that were observed include; orientation of the building, alternative source of energy, provision of courtyard spaces, atriums, and placement of openings, water conservation provisions, and type of cooling, lighting systems adopted in the buildings.

3.6 Sampling Techniques

The samples were selected purposively with respect to the building and the capacity of users it was intended to accommodate as the number of users influences the energy requirement of tech hubs. The selection was based on an average building capacity of two hundred (200) users as this will afford the researcher the opportunity to assess a wide range of green design features within the sample size selected.

3.7 Variables Selection and Inclusion.

Variables are characteristics or attributes specific to a particular research study. Therefore, to give a full assessment of the selected case studies in the research, the variables which meet the requirements of research questions were used to assess the case studies. The architectural features that have been discussed in the literatures reviewed (Ragheb *et al.,* 2015). These variables highlight the green design features

applied and how they have been used to meet the needs of occupants in order to achieve sustainability within the building.

1. Local materials used.
2. Alternative sources of power (biomass fuel, passive solar energy photovoltaic panels, hydroelectric power, tidal power
3. HVAC (Passive cooling and heating systems).
4. Green building components (walls and roofs).
5. Waste and storm water management

The measurement scales in Table 3.1 are expressed numerically. This scale is used to assess the level of implementation of green strategies in the tech hubs that were assessed.

Table 3.1 The study variables and measurement scale

Variables	Specification	Measurement
V1	Use of local materials for wall, roof and floor	(1) Natural
V2	Passive solar use	(2) Semi Natural
V3	Lighting, cooling and heating systems	(3) Semi Artificial (4) Artificial
V4	Outdoor sitting, Gazebo's and Courtyards	(1) One (2) Two
V5	Waste and Storm Water Management Systems	(3) Three or more (4) None

Source: (Ragheb *et al.*, 2015)

3.8 Method of Data Analysis

The researcher employed the use of descriptive statistics which includes frequencies and percentages to present the data collected from the field during the survey. The data was then analysed with statistical programmes for social sciences (SPSS) and the results were presented in tables and charts.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

This chapter show the results from the field work that was carried out and the finding from the assessment of five local and three foreign case studies. An in-depth understanding on the tech hubs centres was conducted while the other three foreign cases studies provide an avenue for comparative analysis of what is obtainable locally and internationally. The researcher has also looked at the constraint and opportunities to the integration of green strategies in the selected tech hubs in which the basis of how the

design is derived with regards to the study area is outlined. It further explains the type of spaces provided, the building materials used, the construction techniques adopted and the various segments of the green strategies applied were outlined.

4.1 Identification of the Existing Green Strategies That Have Been Integrated in Tech Innovation Hubs

The established variables gotten from the literature review were observed in some buildings which served as case studies for the project, a total number of 5 buildings were chosen because the researcher believed they will provide the needed data for the thesis. The questionnaires were administered and the resulting data was recorded and analyzed. The established variables observed include: Orientation, Alternative source of power, Sun shading devices, green outdoor spaces and indoor lightning and ventilation.

4.1.1 Orientation of buildings

Orientation is the way a building is positioned on a site. Buildings that are originally planned and oriented well during the planning stages serve as a great medium to promote passive comfort. In tropical areas, the best orientation of buildings is to have the longer side of the building along the east-west axis which helps reduce the areas exposed to heat gain and hence ensuring little cooling is required to maintain good indoor comfort. (Adebisi et al 2019). However, Houses can be zoned to ensure different spaces receive sunlight at different times of the day.

As shown in Table 4.1 the orientation of the five buildings were studied with regards to sunrise and sunset. Only two of the buildings out of the five studied are well oriented namely, YIN Hub and Enspire Hub. The other three (3) buildings were not properly

oriented and this will affect the buildings overall performance as they will rely more on alternative sources of cooling.

Table 4.1 Orientation of the tech hubs buildings

S/N	List of Tech Hubs	North-South	West - East	In Between
1.	Aiivon Hub	1	0	0
2.	Ventures Park	1	0	0
3.	YIN Hub	0	1	0
4.	DD-Hub	0	0	1
5.	Enspire Hub	0	1	0

Source: Author's Work (2019)

4.1.2 Alternative sources of power supply

An alternative source of power is a backup source used in the advent of failure from the main power source or a more sustainable means of generating power as opposed to the main source of power.

The opposite of renewable energy is non-renewable energy which includes things like fossil fuels, they are regarded as non-renewable because they replenish over a long period of time or never at all. These finite sources have been utilized more over time despite being unequally shared amongst nations unlike renewable sources that are everywhere. Reducing a country's dependence of non-renewable sources of energy can boost their security by reducing exportation and also overall increase their health as non-renewable energy sources are harmful to people and the environment.

The result reveals the alternative sources of power used by the tech hubs as shown in Table 4.2. Two of the five hubs make use of green renewable energy which is shown with the adoption of the solar panels. Only Enspire Hub rely of rechargeable batteries, however all the Five (5) building make use of generators which runs on petrol or diesel.

Table 4.2 Alternative source of power

S/N	List of Tech Hubs	Solar Panels	Recharge-able Batteries	Generator
1.	Aiivon Hub	1	0	1
2.	Ventures Park	1	0	1
3.	YIN Hub	0	0	1
4.	DD-Hub	0	0	1
5.	Enspire Hub	0	1	1

Source: Author's Work (2019)

4.1.3 Sun shading devices on buildings

Sun Shading Devices are used to block solar radiation on a building. They can be applied either on the exterior or interior of a structure and they consist of mechanisms like cantilevers, eaves projections, fins, textile materials and louvers which can be mounted permanently or be flexible and moveable. Sun shading devices are primarily used to aid the creation of thermal comfort in buildings throughout all seasons.

Radiation is very vital in the achievement of thermal comfort, and sun shading devices are utilized to either aid or reduce radiation in buildings thereby aiding the thermal comfort. They generally reduce heat loss or gain depending on the season thereby reducing reliance on mechanical means of regulation thus reducing energy costs. Additionally, they increase the amount of daylight building occupants get, the amount of glare filtered through the building envelope, general energy optimization, and they give a sense of security and privacy (Hart and Ahuja, 1996).

From the data in Figure 4.1, it is observed that 100% of the buildings made use of vertical sun shading device, while 50% of the buildings use horizontal sun shading devices. The result shows that more than one type of sun shading device was adopted by the hubs.

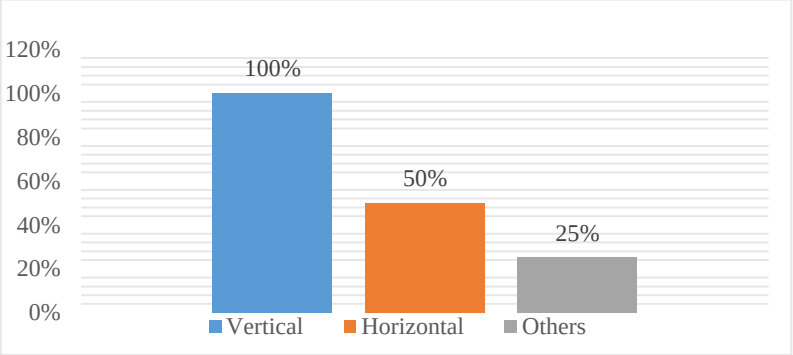


Figure 4.1: Sun Shading Devices used in the Building

Source: Author's Work (2019)

4.1.4 Courtyards and atriums in the buildings

The results from Figure 4.2 show that courtyards have the highest frequency 40% as it was the most commonly adopted green outdoor space within the hubs, followed by gardens and covered porches, however sit-outs had the lowest 10% green spaces that was integrated in the design.

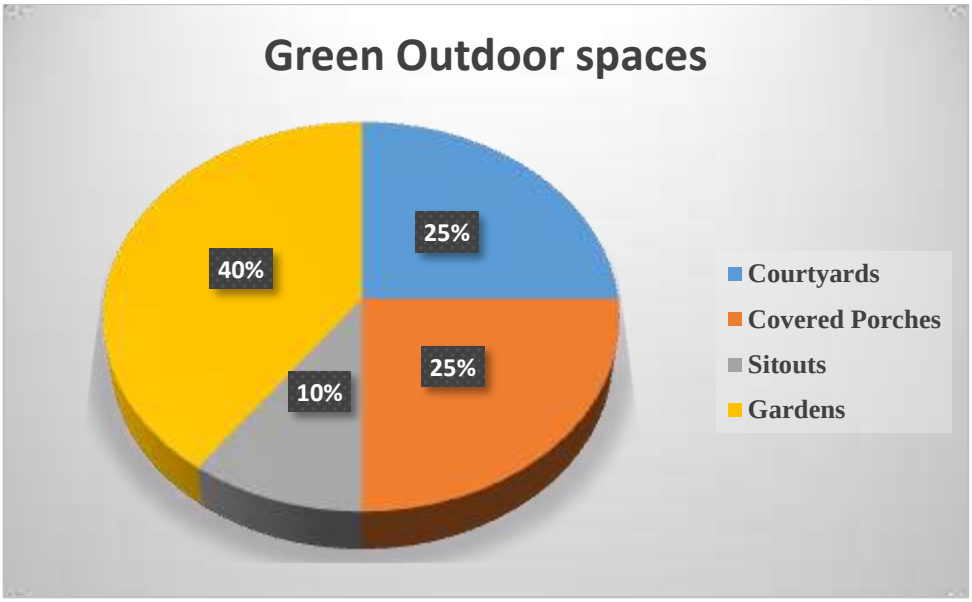


Figure 4.2: Green outdoor spaces

Source: Author's Work (2019)

4.1.5 Type of cooling and lighting systems adopted in the buildings

The data collected shows that the tech hubs studied rely mostly on mechanical cooling and lighting systems as most of the spaces do not have direct window openings to the natural environment. In the researcher's view this is partly because three out of the five hubs buildings that were studied are not owned by the tech companies but rather, they use rented space. Thus, there is a need to have properly designed buildings made specifically for Tech activities in order to tailor fit the specific requirements needed to achieve sustainability and efficiency.

Plate I: Indoor space with no access to natural lighting and ventilation at Aivon Hub

Source: Author's Work (2019)

Plate II: Indoor space with no access to natural lighting and ventilation at Enspire Hub respectively.

Source: Author's Work (2019)

4.2 Case Studies

A total of 5 case studies were chosen, they were picked via purposeful sampling and were specifically selected because the researcher believed they will provide the necessary data for the thesis research. The following coding will be used to properly assess the variables.

Coding:

Orientation: O

Alternative source of power: AP

Sun shading devices: SS

Courtyards and Atriums: CA

Cooling and Lighting systems: CL

4.2.1 Aiivon Hub

Aiivon hub is in Abuja in the heart of the commercial centre. It is a creative digital centre that supports the development of Tech and Tech related things in West Africa. It has been home to numerous start-ups, averaging so far over 60 start-ups who were all given adequate resources needed to carry out their varying and necessary activities. It has fully furnished and serviced working areas, conveniences, co working spaces, business support and mentorship opportunities and also access to funding and networking for seamless market penetration. The hub is run by a motivated group of individuals who are aimed at creating solutions for the local community by using the creativity inspired from the work environment. They partner with The British Council, NITDA and other reputable organizations, and use their platform to influence several Nigerians who are aspiring to become successful entrepreneurs particularly in the creative and information technology industries**.**

After being accessed with the observation schedule and questionnaires, Aiivon hub's level of green strategies integrated with the building has been properly accessed in the Table 4.3

Table 4.3 Analysis of green strategies adopted in Aiivon hub

Strategies	Code	Scoring
Orientation	O	×
Alternative source of power	AP	✓
Sun shading devices	SS	✓
Courtyards and Atriums	CA	✓
Cooling and Lighting systems	CL	×

Source: Author's Work (2019)

From the table it is evident that Aiivon hub adopted 60% of the green strategies in their design of their working space.

4.2.2 Ventures Park

Ventures Park is a Co-working facility located in the serene environment of Abuja where freelancers, entrepreneurs, and bright minds, who have common interests, attitudes, and goals can express their creativity while collaborating and building their dreams. It is furnished with a gym, offices, high-speed internet, and artsy finishes. With their modern spaces, co-working and private facilities at reasonable prices they give a smooth working experience also with flexible payment options.

After being accessed with the observation schedule and questionnaires, Ventures park level of green strategies integrated with the building has been properly accessed in the Table 4.4.

Table 4.4 Analysis of green strategies adopted in Ventures Park

Strategies	Code	Scoring
Orientation	O	×
Alternative source of power	AP	✓
Sun shading devices	SS	✓
Courtyards and Atriums	CA	✓
Cooling and Lighting systems	CL	×

Source: Author's Work (2019)

From the table it is evident that Ventures Park adopted 60% of the green strategies in their design of their working space.

4.2.3 Yin Hub

Founded by Mr. Abu Andrew who recently won the Association of Telecoms Companies of Nigeria (ATCON) 4th Edition of Nigerian Tech Innovations & Telecoms Awards (NTITA) 2020 young ICT Advocate of the year 2020 award making it almost a decade of consistency and impact in developing digital skills for young people. It is located at 5 Agatu Street Area 11 Garki, Nigeria and is known as a social enterprise focused on the development of indigenous technologies , capacity building, bridging skill gaps and using technology to develop our local communities and a place where young innovators get mentored for the future. After being accessed with the observation

schedule and questionnaires, Yin Hub level of green strategies integrated with the building has been properly accessed in the Table 4.5.

Table 4.5 Analysis of green strategies adopted in Yin Hub

Strategies	Code	Scoring
Orientation	O	✓
Alternative source of power	AP	×
Sun shading devices	SS	✓
Courtyards and Atriums	CA	×
Cooling and Lighting systems	CL	×

Source: Author's Work (2019)

From the table it is evident that Yin Hub adopted 40% of the green strategies in their design of their working space.

4.2.4 DD-Hub

DD-Hub is a tech-based innovation hub designed to support the creation of social impact and commercial start-ups with the aim of fostering development through creativity and innovation. DD Hub was founded in 2014 with its corporate headquarters in Abuja and training hub in Kano. In addition to running a training hub that empowers youths with digital skills, DD-Hub also offers co-working, incubation and acceleration spaces where a community of tech enthusiasts can collaborate on developing and scaling digital products. Training on digital skills offered by the hub includes mobile and web development, digital graphics (including UI and UX), film making, animation, big data mining, analysis and visualization, remote sensing and GIS as well as business modelling.

After being accessed with the observation schedule and questionnaires, DD Hub's level of green strategies integrated with the building has been properly accessed in the Table 4.6

Table 4.6 Analysis of green strategies adopted in DD Hub

Strategies	Code	Scoring
Orientation	O	×
Alternative source of power	AP	×
Sun shading devices	SS	✓
Courtyards and Atriums	CA	✓
Cooling and Lighting systems	CL	×

Source: Author's Work (2019)

From the table it is evident that Yin Hub adopted 40% of the green strategies in their design of their working space.

4.2.5 Enspire Hub

Enspire hub is located in Abuja. It was birthed in 2013 and has over the years seen over 200 start-ups and individuals. It is focused on early-stage start-ups and aimed at helping budding businesses grow. They also have a mentorship program quarterly every year for start-ups. Currently they are part of the major initiatives of Abuja Technology Village Free Zone Company (ATV). It seeks to kindle economic growth and sustainable job creation through enterprise development, innovation, entrepreneurship, and technology commercialization by providing training, mentoring, networking opportunities and access to investors.

After being accessed with the observation schedule and questionnaires, Enspire Hub's level of green strategies integrated with the building has been properly accessed in the Table 4.7

Table 4.7 Analysis of green strategies adopted in Enspire Hub

Strategies	Code	Scoring
Orientation	O	✓
Alternative source of power	AP	✓
Sun shading devices	SS	✓
Courtyards and Atriums	CA	✓
Cooling and Lighting systems	CL	×

Source: Author's Work (2019)

From the table it is evident that Enspire Hub adopted 80% of the green strategies in their design of their working space

4.3 Design Proposal Based on Established Variables

Based on the data gathered, the researcher designed a tech hub for Minna Niger state integrated with the established variables to create a sustainable and functional design.

4.3.1 Site location

The site is in Minna Niger state, near the building's material market. The location is serene and quiet which is perfect for Tech related matters that involve a lot of thinking and innovation. The location is also home to a lot of green vegetation which serve as the perfect background emphasizing the researchers focus in this thesis.

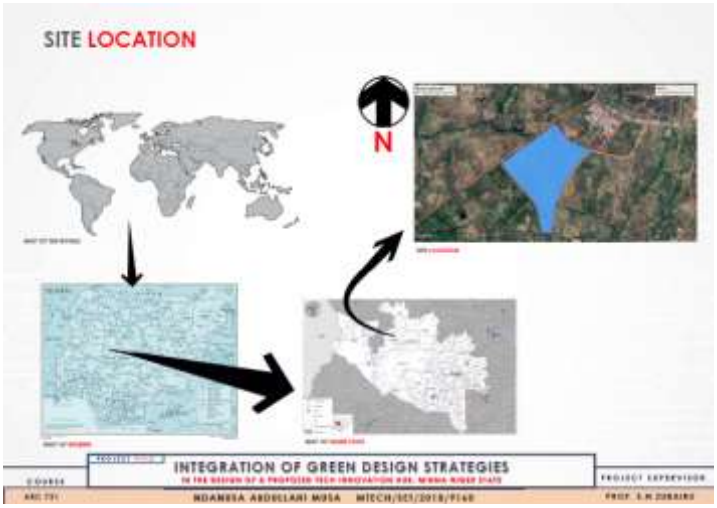


Plate III: Site location

Source: Author's Work (2019)

4.3.2 Site analysis

The site was appropriately analyzed considering wind and sun direction, climate and weather patterns, topography and other variables to ensure the proper orientation of the building for maximum benefit.

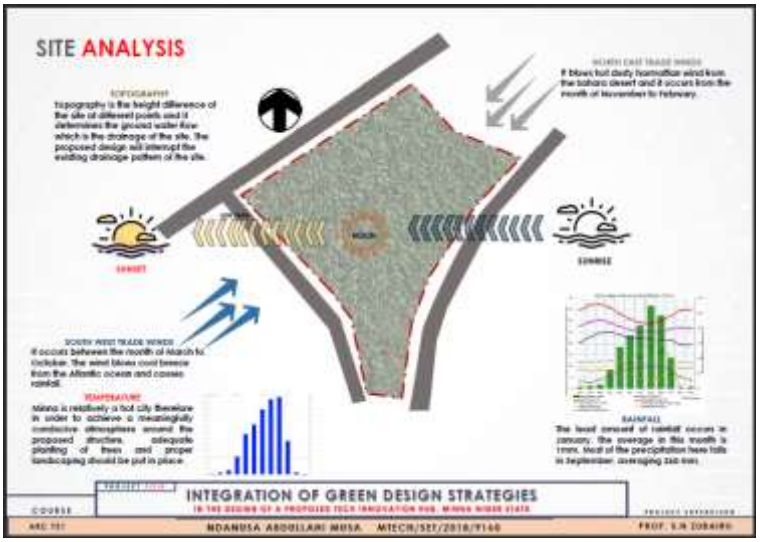


Plate IV: Site Analysis

Source: Author's Work (2019)

4.3.3 Site plan

The site was planned with considerations for the analysis previously done and also in alliance with the concept of the main building which is a CPU used in technical hardware.

Plate V: Site Plan

Source: Author's Work (2019)

4.3.4 Conceptual Analysis

The concept of the main building is a plan concept which flows from the purpose of the building: A Tech hub. A CPU was used as the concept because it is one of the most important elements in Technical Hardware.

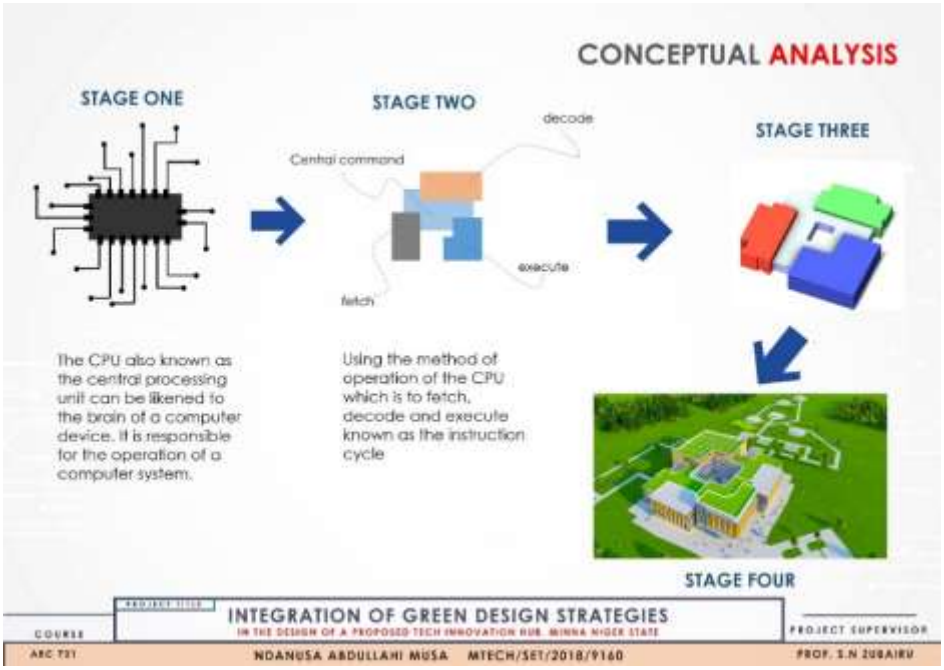


Plate VI: Concept

Source: Author's Work (2019)

4.3.5 The main building

The building consists of 5 floor plans with varying uses on each of them all made to aid the work to be carried out in the building.

Plate VII: The main building

Source: Author's Work (2019)

4.3.6 Design considerations and planning principles

Green strategies were researched on and implemented in the design; some have been previously discussed as variables while others like the green roof were added by the research to enhance the buildings positive attributes.

Plate VIII: Green Roofs

Source: Author's Work (2019)

4.3.7 Construction system

The building uses a simple post and beam system consisting of columns and beam supports. This is a simple yet effective means of construction**.**

Plate IX: Construction system

Source: Author's Work (2019)

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The integration of green strategies is considered as an effective way of negating the increasing greenhouse emissions due to the large energy usage of tech hubs. This strategy when adopted helps in achieving good thermal comfort for the end users of these buildings by ensuring adequate natural lighting and ventilation. More also saving the need for more energy by taking advantage of other renewable sources of energy such as solar, wind and water. The study concludes that across the five case studies there was low-level of integration of green strategies in the buildings and the impact of these strategies do not reflect in the energy requirement of the tech innovation hubs. Furthermore, the study shows that the tech hubs rely mostly on mechanical cooling and lighting systems as most of the spaces do not have a direct window opening to the natural environment. In the researcher's view this is partly due to the fact that three out of the five tech hub buildings that were studied are not owned by the tech companies but rather they are rented. This explains the reason why the specific needs of the tech hub may not have been considered from the conceptual stage of the building design.

5.2 Recommendations

The study recommends the need for the government to enact policies that will encourage the adoption of green strategies in tech hubs in line with what is obtainable in developed countries. The research recommends that there is the need for sensitization of the professionals within the built environment on the benefits of adopting green strategies from design stage and construction stage to achieve rationalization of energy consumption in buildings.

REFERENCES

Adebisi, I. K., Kunle, A. A., & Okeyinka, R. Y. (2019). Energy Efficient Buildings in Tropical Climate Through Passive Techniques-An Overview. *Journal of Environment and Earth Science,* 8(4), 45-50.

Asif, M., Muneer, T., & Kelly, R. (2007). Life Cycle Assessment: A Case Study of a Dwelling Home in Scotland. *Building Environment*. 42(1), 1391–1394.

Attaman, O. (2010). *Green Architecture: Advanced Terminologies and Materials*. Avenue, New York: McGraw-Hill Press.

Bribian, I. Z., Capilla, A.V., & Uson, A. A. (2011). *Life cycle assessment of building materials: Comparative analysis of energy and environmental impacts and evaluation of the eco-efficiency improvement potential.* Retrieved on December 3, 2019 from: http://dx.doi.org/10.1016/j.buildenv. 2019.12.002.

Chen, Y.S., Lai, S.B., & Wen, C.T. (2007). The Influence of Green Innovation Performance on Corporate Advantage in Taiwan. *Journal of Business Ethics*. 67, 331–339.

Coward, C. (2014). Private Then Shared. *Communications of the ACM*. 57(8), 29-30.

Creswell, J. W. (2012). *Research Designs*. *Educational research: Planning. Conducting, and Evaluating* (pp. 260, 375-382). New Jersey, Prentice Hall: Upper Saddle River NJ.

Cullen, H. J. (2010). *Overview of green buildings*. Retrieved on August 22, 2019 from: http://epa.gov/greenbuildings/pubs/gbstats.

Damati, S. H. (2013). *Principles in Green Architecture: An Inquiry into the Evaluation Criteria of Green Awards*. (MSc Published Thesis submitted to the Graduate School of Natural and Applied Sciences of Middle East Technical University, Ankara, Turkey). Retriever on December 3, 2019 from http://www.ecobooks. com/ books /history.htm.

De-Bastion, G. (2013). *Technology Hubs, Creating space for change: Africa's technology innovation hubs*. Retrieved on November 17, 2019 from https://10innovations.alumniportal.com/fileadmin/10innovations/dokumente/GIZ10innovations-01_Technology-Hubs-Brochure.pdf, checked on 3/15/2016.

Dimoudi, A. & Tompa, C. (2008). Energy and Environmental Indicators Related to Construction of Office Buildings. *Resources Conservation and Recycling*, 53(1), 86–95.

Friederici, N. (2014). *The business models of mlabs and mhubs: An evaluation of infodev's mobile innovation support pilots. Information Development, World Bank*. Retrieved on August 10, 2019 from http://www.infodev.org/ mobile businessmodels.

Gathege, D., & Moraa, H. (2013). *Draft Report on Comparative Study on Innovation Hubs across Africa. Nairobi: iHub Research*. Retrieved on August 10, 2019 from http://research.ihub.co.ke/up-loads/2013/may/1367840837__923.

Gil-Mastalerczyk, J. (2016). *Sustainable design in the contemporary architecture of tall*. New York, USA: McGraw-Hill.

Godfaurd, J., Clements-Croome, D., & Jeronimidis, G. (2005). Sustainable Building Solutions: A Review of Lessons from the Natural World. *Building Environment*. 40, 319–328.

Graham, P. (2003). *Building Ecology: First Principles for a Sustainable Built Environment*. Oxford, UK: Blackwell Publishing.

Hart, S.L. & Ahuja, G, (1996). Does it Pay to Be Green. *Business Strategy Environment*. 5(1), 31–37.

Kelly, T. & Firestone, R. (2016*). How Tech Hubs are helping to Drive Economic Growth in Africa (Background Paper for the World Development Report 2016: Digital Dividends). Washington, DC: The World Bank*. Retrieved on December 12, 2019 from https://openknowledge.worldbank.org/bitstream/handle/10986/23645/WDR16-BP-How-Tech-Hubs-are-helping-to-Drive-Economic-Growth-in-Africa-Kelly-Fire-stone.pdf.

Kim, J., (2008). *Sustainable Architecture Module: Introduction to Sustainable Design. National Pollution Prevention Centre for Higher Education, University of Michigan*. Retrieved on November 22, 2019 from http://deepblue.lib.umich.edu/handle/ 2027.42/113525.

Mohammadjavad, M., Arash, M., Airya, N., Setareh, G., Narjes, E., (2014). Dilema of Green and Pseudo Green Architecture Based on LEED Norms in Case of Developing Countries. *International Journal of Sustainable Built Environment*. 3(1), 235-246.

Nicolas, F. (2014). *What is a Tech Innovation Hub Anyway? Oxford Internet Institute, University of Oxford*. Retrieved November 20,2019 from http://cii.oii.ox.ac.uk/2014/09/16/what-is-a-tech-innovation-hub-anyway.

Njeri, M. (2010). *Contemporary work environments for information communication technology innovation and enterprises* (Bsc.Thesis). Retrieved on January 22, 2020 from: http:/www.google.com/m?q=njeri+2010+ict&client=ms-opera-ms.

Oliveira, L.H., Iiha, M.S.O., & Gonçalves, O. M. (2009). Environmental Assessment of Residential Buildings with an Emphasis on Water Conservation. *Building Services Engineering Research and Technology*. 30, 15–26.

Oltra, V., & Saint J. M. (2009). Sectoral Systems of Environmental Innovation: An Application to the French Automotive Industry. *Technological Forecast Soc. Chang*. 76, 567–583.

Oluigbo, S.N. (2010). *Context and Applications of Case Studies in Architectural Research,* (Department of Architecture,Ahmadu Bello University, Zaria). Retrieved on October 17, 2019 from http://www.tdx.cat/ TDX-0122110-180946.

Osama, A.I., Mohamed, I. A., & Ahmed, K. M. (2017). Applying the Principles of Green Architecture for Saving Energy in Buildings. *International Conference – Alternative and Renewable Energy Quest, AREQ,* 2017, 1-3.

Ponting, C. (2007). *A new Green History of the world: The Environment and the collapse of Great Civilizations*. Retrieved November 11, 2019 from http://www.ecobooks.com/books/history.htm.

Ragheb, A., El-Shimy, H., & Ragheb, G (2015). Green architecture: A concept of buildings. *Social and behavioural sciences.* 216, 778-787.

Roy, M., (2008). *Importance of green architecture today*. (Department of Architecture, Jadavpur University, Kolkata, India). Retrieved on December 16, 2019 from https://sari-energy.org/oldsite/PageFiles/What_We_Do/activities/ SAWIE /SAWIE_112008/SAWIE_112008/5.Importance%20of%20Green%20Architecture%20today%20-%20Ms%20Madhumita%20Roy.pdf.

Saraswati, J. (2014). Konza City and the Kenyan Software Services Strategy: The Great Leap Back-Ward. *Review of African Political Economy*. 41(1), 128–137.

Sassi, P. (2006). Strategies for Sustainable Architecture. *World Journal of Engineering and Technology*. 4(2), 3-14.

Sheweka, S. & Magdy, N. (2011). The Living Walls as an Approach for A Healthy Urban Environment. *Journal of Energy Procedia*. 6(2), 592–599.

Sinha, A., Gupta, R. & Kutnar, A. (2012). Sustainable Development and Green Building. *Journal of Wood Industry*. 64(1), 45-53.

Sloane, P. (2011). *A guide to open innovation and crowdsourcing: expert tips and advice*. London, UK: Kogan page press.

Stallworth, J. O. E. & Kleiner, B. H. (1996). Recent Developments in Office Design. *Journal of Facilities*. 14 (1), 34-42.

Stefan, S. (2006). *Cosmos of the ancient: The Greek philosopher on myth and cosmology (3rd Ed.)*. Stockolm, Sweden: Create space independent press.

Sustainable Architecture and Building Design, SABD (2005). *Passive and active sustainable strategies*. Retrieved on September 20, 2019 from http://www.arch.hku.uk/research/BEER/sustainability.html.

United Nations Population Funds, UNFPA (2013). Unleashing the potentials of urban growth. Retrieved on October 10, 2019 from http;/www.unfpa.org/publications /state-world-population-2013.com.

United Nations World Water Development Report, WWDR (2015). Water for People, Water for Life. Retrieved on October 27, 2019 from http;/www.unwwdra.org /publications/water-for-world-population-2015.html

Veal, A. J. (2006). *Research Methods or Leisure and Tourism. Third Edition*. London: Prentice Hall.

Wadel, G. (2009). *Sustainability in Industrialized Architecture: Modular Lightweight Construction Applied to Housing* (Doctoral Thesis, Polytechnic University of Catalonia- Department of Architectural Constructions). Retrieved on October 17, 2019 from http://www.tdx.cat/ TDX-0122110-180946.

Wheeler, A. (2015). *Building A Shared World as A Definition of Sustainable Architecture*. (Proceeding of the 80th Architecture Conference Proceedings and Presentations, Nordic Environmental Social Sciences, at Iowa State University, Trondheim, Norway). Retrieved October 20th 2019 from http://lib.dr.iastate.edu/ arch_conf /80.

Wilson, A., Uncapher, J. L., McManigal, L., Lovins, H. L., Cureton, M., & Browning, W.D. (1998). *Green Development: Integrating Ecology and Real Estate*. New York, USA: John Wiley and Sons, Inc.

Woolley, T. (2006). *Natural building: A Guide to Materials and Techniques. Philadelphia*. USA: Crowood Press.

Yin, R. K., (2009). *Case study research: Design and methods (4th Ed.)*. Thousand Oaks, California, USA: Sage.

Yudelson, J. (2009). *Green Building through Integrated Design. Syracuse*, NY, USA: McGraw-Hill Publishing.

APPENDICES

Appendix A: Questionnaire

ASSESSING THE LEVEL OF AWARENESS AND INTEGRATION OF GREEN STRATEGIES IN TECH INNOVATION HUBS IN NIGERIA

Dear respondent,

This questionnaire is designed to elicit information for a Master's thesis in Architecture titled **"Integration of Green Strategies in the Design of Tech Innovation Hub in Minna, Niger State Nigeria**".

The study aims to identify the green design techniques and to investigate how they have been adopted in Tech Innovation Hubs in Nigeria to foster sustainability. All information provided will be treated with strict anonymity and results will be published in an aggregated form. The researcher is of the belief that your contributions will be of great help to this study, hence you are urged to kindly give candid responses to the questions below. Thanks.

VARIABLES UNDER CONSIDERATION

1. Building Orientation
2. Vegetation Cover
3. Building Materials used
4. Passive solar use
5. Lighting, cooling and heating systems
6. Outdoor sitting, Gazebos and Courtyards
7. Waste and Storm Water Management Systems

Appendix B: Checklist

FEDERAL UNIVERSITY OF TECHNOLOGY

INTEGRATION OF GREEN STRATEGIES IN TECH INNOVATION HUBS IN NIGERIA

OBSERVATION SCHEDULE/CHECK LIST

1. The orientation of the building longer side with reference to solar radiation

a. North-South. b. East-West c. others

2. Types of vegetation cover

a. Trees (species) b. Shrubs (species) c. Lawns d. flowers

3. Number of spaces with indoor plants (e.g flowers and shrubs)

a. None b. 1 c. 2. d. 3. e. 4 & Above.

4. Distance of vegetation from the closest building.

a. Less than a meter b. 1-2 meters c. 3 meters or more

5. Number of water bodies present (e.g. Fountain)

a. None b. 1. c. 2. d. 3. e. 4 & Above.

6. Colour of interior wall paint and finishes

a. Bright colours (e.g. white, beige, yellow, green). b. Dark Colours (purple, black, brown, blue.

7. The type of wall material used

a. Brick b. Hollow Sandcrete Block C. Aluminium Cladding d. Wood

8. The type of roofing material used

a. Concrete decking b. Aluminium roof c. thatch roof. D. wooden roof

9. The type of floor material used

a. Tiles b. Terrazzo c Wood d. Concrete

10. Number of courtyards provided in the tech hub.

Please tick (v) as appropriate

SECTION B: Social Demographic of Respondents (Built Environment Professionals)

1. Gender: Male ( ) Female ( )

2. Age: Below 18 ( ) 19-30 ( ) 31-40 ( ) 41-50 ( ) 51 and above ( )

3. Educational Qualification:

a. ND/NCE ( ) b. Bsc/HnD ( ) c. MSc ( ) d. Ph.D ( )

4. What is your profession?

a. Structural Eng. ( ) b. Architect ( ) c. Quantity Surveyor ( ) d. Estate Manager ( )

e. Builder ( )

5. What is your employment status?

a. Unemployed b. Working with Government c. Private firm/Freelance

6. How long have u been working in the building industry?

a. Less than a year ( ) b. 1-5 years ( ) c. 6-10 years ( ) d. 20 years and above ( )

SECTION C: AWARENESS OF SUSTAINABILITY

Built Environment Professionals questionnaire

7. What do you understand with the concept of sustainability? …….. ……..

8. What aspect of sustainability do you implement in designs? ……..……

9. Are you aware of any Sustainable construction techniques? a. Yes ( ) b. No ( )

……..……

10. Are staff of your organization intimately involved in sustainability matters? Yes ( ) No ( )

……..

12. Can you highlight any sustainable strategy that can be used in a tech hubs? Yes ( ) No ( )

……

SECTION D: STORM AND RAIN WATER MANAGEMENT

Staff and Facility Managers of the Tech Hubs

13. What are the source of water supply in tech hubs? a. Water board b. Boreholes c. Well water d. Storm water.

14. Does the tech hub collect rain water for re-use? Yes ( ) No ( )

15. What is the daily water requirement of the tech building? a. Less than 240 Litres b. above 250-300 Litres c. 301-350 Litres d. above 351 Litres

16. Any on-site wastewater treatment facilities in the tech hub? Yes ( ) No ( )

17. Can confirm that the water supply in the tech hub is adequate? Yes ( ) No ( )

SECTION E: ENERGY CONSUMPTION

18. Does the tech hub have an alternative source of energy? a. Yes ( ) b. No ( )

…….

19. Is adequate natural lighting admitted into the tech hub building through openings?

a. Yes ( ) b. No ( ) ……..

20. Is natural ventilation in the tech hub building adequate?

a. Yes ( ) b. No ( ) ……

21. Does the landscape effectively reduce the impact of solar radiation on the building?

a. Yes ( ) b. No ( )

Appendix C: Botswana innovation hub

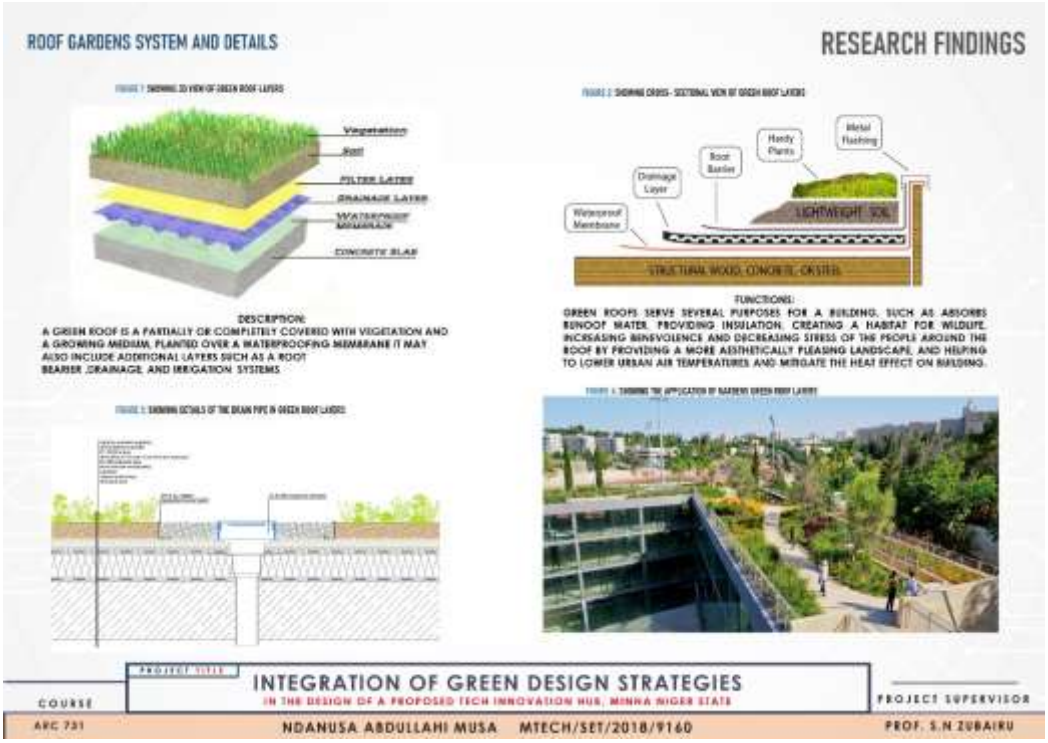
Appendix D: Microsoft New England

Appendix E: Googleplex

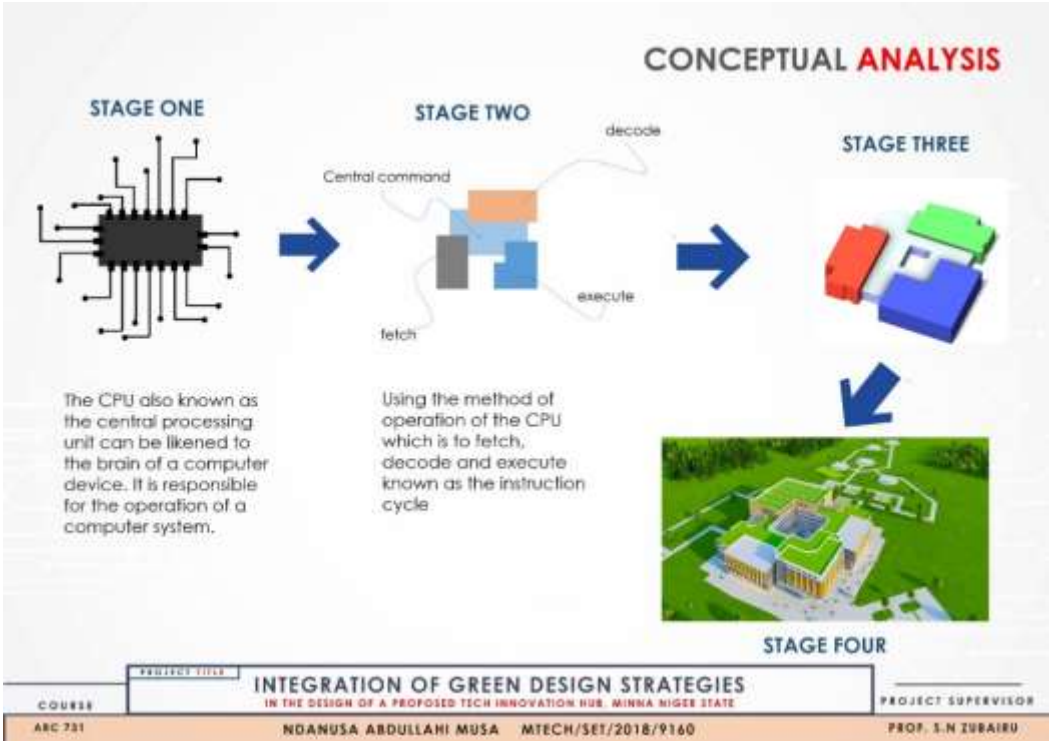
Appendix F: Aiivion innovation hub

Appendix G: Ventures park

Appendix H: Green roof



Appendix I: Conceptual analysis



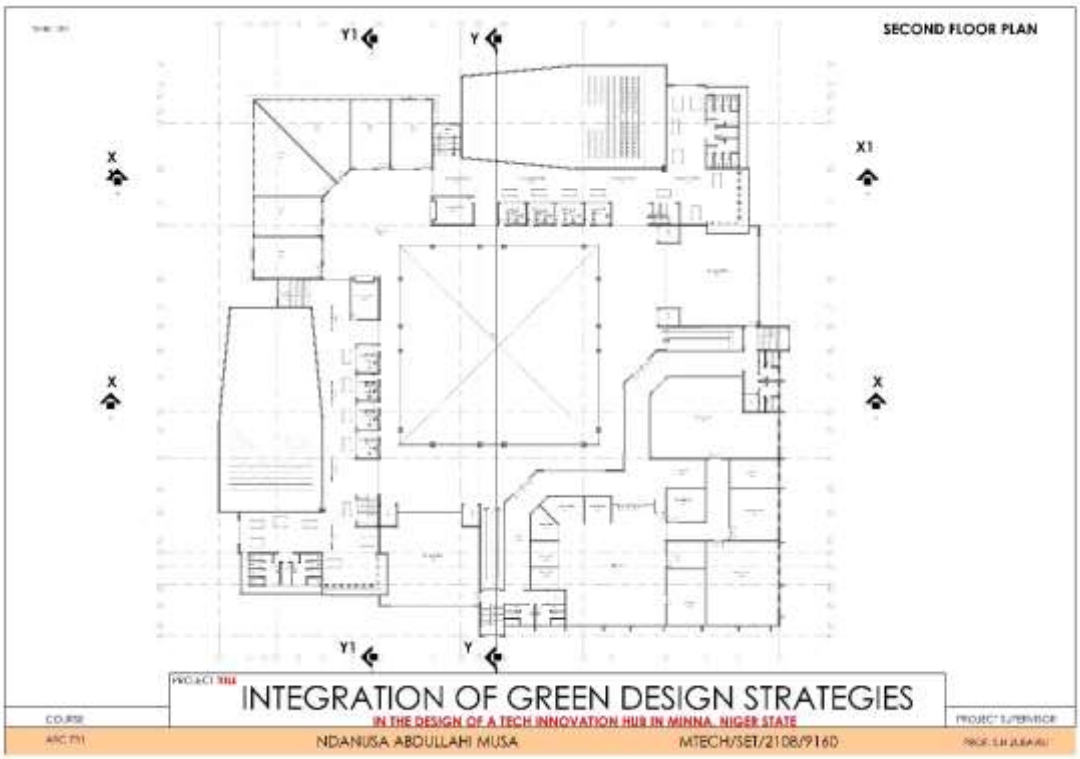
Appendix J: 3D

Appendix K: Site plan

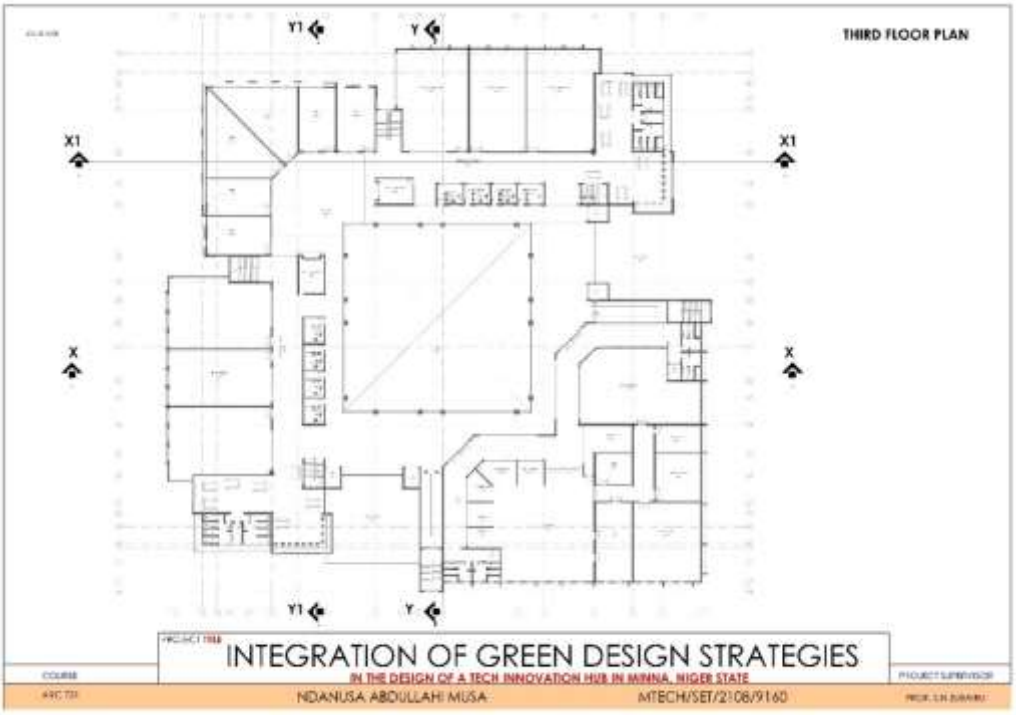
Appendix L: Ground floor plan

Appendix M: First floor plan

Appendix N: Second floor plan

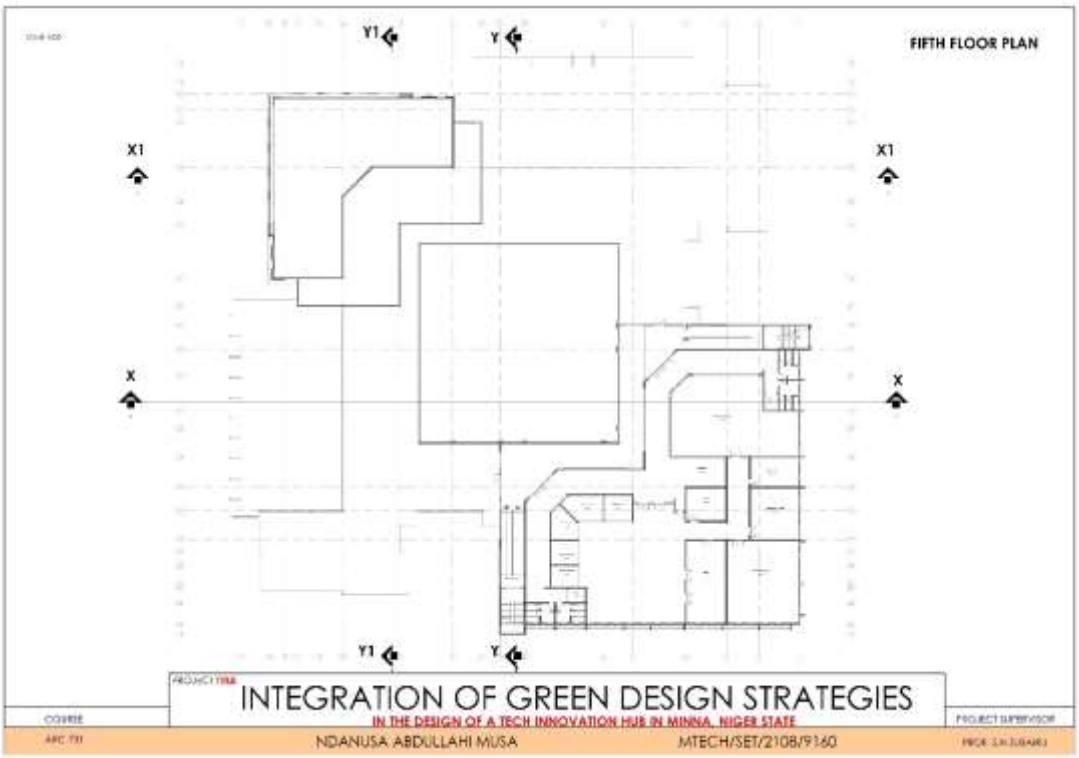


Appendix O: Third floor plan

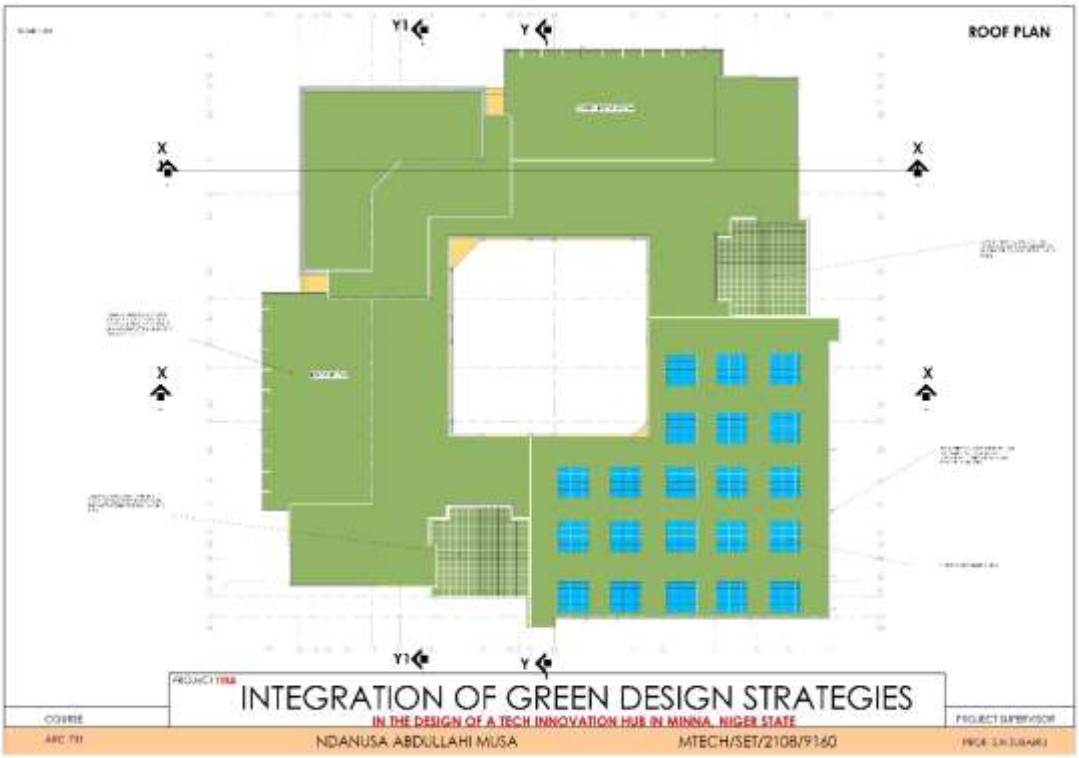


Appendix P: Fourth floor plan

Appendix Q: Fifth floor plan

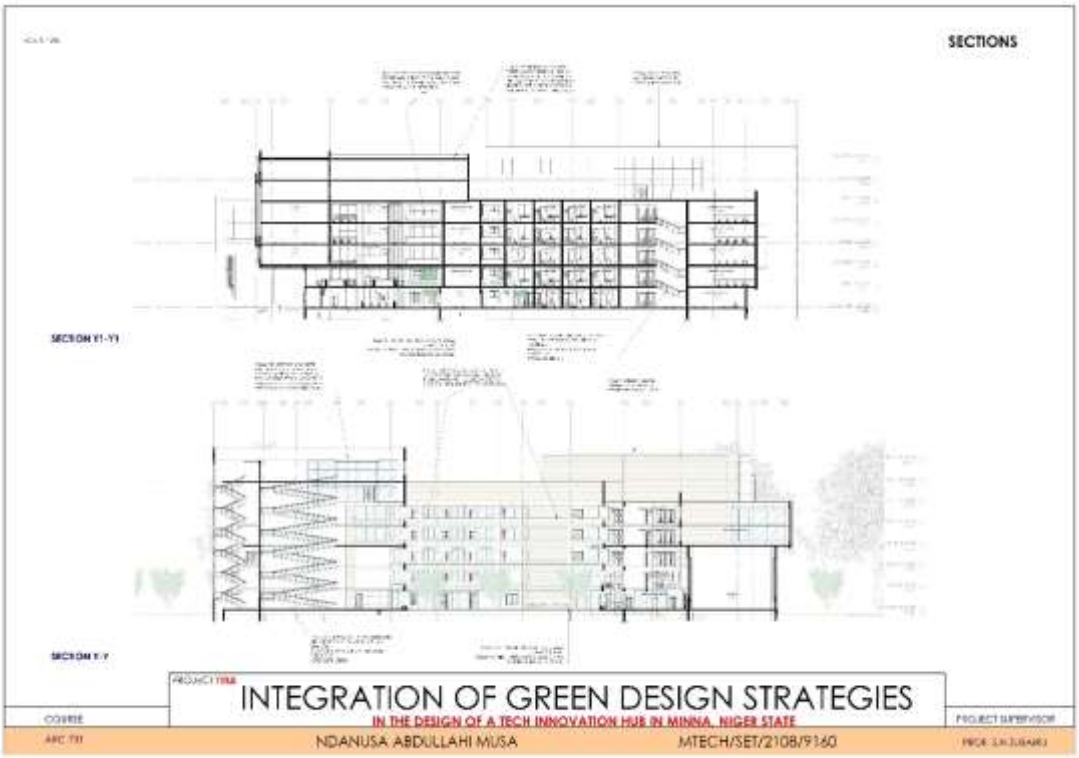


Appendix R: Roof plan



Appendix S: Section X-X

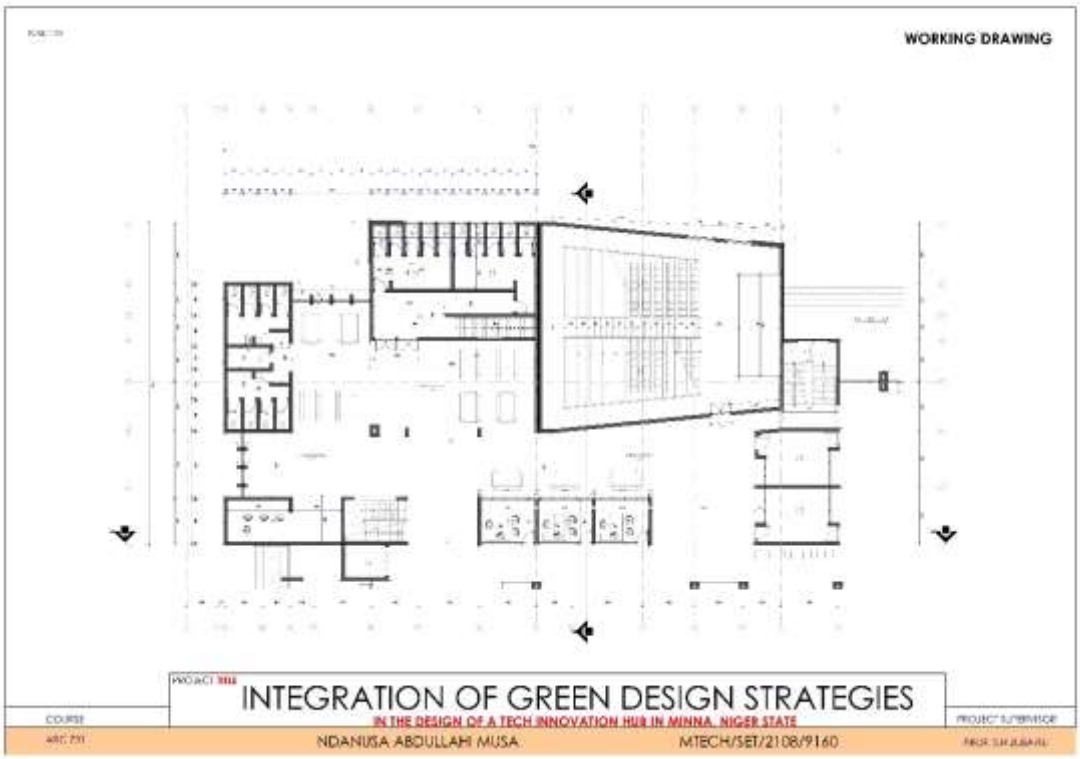
Appendix T: Section Y-Y



Appendix U: Elevations I

Appendix V: Elevations II

Appendix W: Working drawing



Appendix X: Details