

Flexible Interior Space Through Modular Design In Vocational Training Institute

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Environmental Design and Management,**

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(M.Sc)Architecture**

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Certification

This is to certify that Bamiduro, Akinkunmi E. with matriculation number LCU/PG/002063 carried out this research work titled “Flexible Interior Space Through Modular Design In Vocational Training Institute” in the Department of Architecture, Faculty of Environmental Design and Management, Lead City University, Ibadan, Oyo state, for the award of Master Degree (M.Sc.) in Architecture and that this has not been previously submitted.

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Dedication

This dissertation is dedicated to God Almighty, the source of all knowledge and the world's Saviour.

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Acknowledgement

I want to express my gratitude to everyone who helped me with this M.Sc. thesis.

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Abstract

This research focuses on investigating the imperative interior space flexibility in a Vocational Training Institute and the design approaches that can be adopted to design a Vocational Training Institute in Nigeria. Five case studies were investigated in this study to determine what interventions in design and material have been adopted both locally and internationally to achieve a Training Institute that can be said to be flexible and the mistakes made on the projects to avoid a repetition. This investigation helped to realise design approaches and materials that can be employed to achieve flexibility in a Vocational Training Institute design. The research concludes with the recommendations that can be adopted to achieve flexibility in Vocational Training Institute design.

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Chapter One

Introduction

1.1. Background of the Study

Vocational Training Institute (VTI) concentrates on specific trades and provides practical abilities that permit people to work in certain occupations. Vocational Training Institute is a critical tool for development, worker mobility, flexibility, and productivity, enhancing enterprise competitiveness and restoring labour market imbalances. Different words have been used to characterise analogous aspects of the VTI, which Internship training, vocational education, industrial arts, technical education, Technical/Vocational Education (TVE), and Occupational Education education (OE), Technical Education, Career and Technical Education (CTE), and Vocational Education and Training (VET) are all examples 50. Baird, A. F., Stork, A. L., Horne, S. A., Naldrett, G., Kendall, J. M., Wookey, J., ... & Clarke, A. (2020).

Globally, VTI programs in nations have gotten a lot of attention in the last few years. In 2010, the Organization for Economic Cooperation and Development (OECD) published guidelines on the tools needed to promote VTI based on an assessment of international experience in VTI policy-making across 17 countries. Furthermore, Australia, Austria, and Korea were chosen as OECD country examples to demonstrate varied approaches to VTI. Though it had a young VTI system, Australia was selected because it excelled in VTI research and implemented an evidence-based VTI policy. Australia also had a robust credential framework, one of the first in the OECD to be implemented. The Austrian example, on the other hand, was chosen because it exemplified a long-standing tradition of collaboration with social partners (representative bodies of employees and employers) in which social partners have a true "co-ownership" of VTI procedures.

VTI Curriculums are intended to create employment opportunities and teach self-employment skills, especially in rural areas and unorganised areas. The Nigerian government is promoting these programs as part of its core policy agenda. Hence, the critical research and analytics to impact the development of VTI policy and match it with the labour market demands.

Though the demand for some vocational training institutes has become critical, the resources needed to construct training centres are getting scarcer. The architects' simple traditional practice was to create structures to satisfy particular demands; however, these needs might change over time. As a result, It has become necessary for architects to reconsider their design approach to resolving space issues. Therefore, the required a shift toward greater space flexibility ensures that a building or facility is almost always used according to need. Modern dwelling units' ability to adapt to their users' needs is an important design goal. Mahmoud, H. T. H. (2017). According to Josephat, P. N. (2021). the necessity for newfound adaptability architectural principle has grown due to building end users' quickly changing social needs. As a result of the Spaces must be used for multiple purposes, and they must be adaptable spaces in VTI should be designed so that they could be easily broken down into smaller discrete and scalable sizes without compromising the overall structural stability of the building Adetayo, (2016). Therefore, flexibility, openness, and transparency should be essential prerequisites for future VTI Nunes, T. F. B. (2021).

Combining several needed functions during a building project's predesign and design stages to create space flexibility in buildings has always been present. Therefore, examining such design needs is done so that the activities requiring more space are prioritised above those requiring less space.

Flexibility in places utilised for pedagogical and educational activities, according to Castaldo, V. L., Pigliatile, I., Rosso, F., Cotana, F., De Giorgio, F., & Pisello, A. L. (2018). poses several issues in today's environment. Essentially, the utilisation of these places for activities varies throughout the day and over long periods. The need for innovative opportunities for obtaining flexibility of space, such as the modular concept in space planning, arose from the necessity to in an interior space, accommodate a variety of pedagogical and didactic activities. The anticipated outcome of implementing such notions is a versatile learning environment that allows for a wide range of educational methods and learning experiences The modular notion in space design has been around for a long time, but it has been chiefly used in building construction parts and wall placement for structural reasons. The use of modular planning principles was introduced to improve the flexibility of space to cater for multiple functions that might use identical facilities, lowering total operating costs and improving sustainability. Because walls and interior components can be assembled and dismantled in various formats to match the required current user needs, the modular idea of planning allows even more space flexibility Goh, M., & Goh, Y. M. (2019). A modular system comprises separate partition parts that are adaptable and reusable to accommodate different sizes to fulfil various duties while maintaining a diverse working environment Gorgolewski, M. (2017). The advantages of using modular concepts to gain flexibility, such as demolishing a concrete block wall during the remodelling of an existing area into new configurations by end users, include effective use of space, economic effectiveness, and reduction of construction waste.

A modular system's main advantage is the ease with which it can be erected and the time it takes to create the desired environment. Regrettably, various structure designs in Nigeria, including the Vocational Training Institute, are usually specialised in nature and

not adaptable 46. Afolabi, A. O., Oluwatayo, A., Oyeyipo, O., Ojelabi, R., & Fagbenle, O. (2018). resulting in buildings that are typically unsuitable for other purposes when the Vocational Training Institute are not in use.

1.2. Statement of the Problem

Vocational Training Institutes have been designed and built over time with the sole purpose of training individuals in a classroom using less sophisticated machines and mostly manual tools. It is done without considering that as technology advances, these small machines and tools will be replaced by much more sophisticated machines, necessitating larger spaces but significantly improving the impactation method. We must also consider that a vocational training institute is not just a non-tertiary institution but also a type of industry where products can be shown and sold.

Those structures were built with no room for flexibility. So they cannot adapt or accommodate new larger machines or populations without requiring the demolition of some building components, wasting resources and time, and, most importantly, posing a threat to the structure's structural stability if these walls are load-bearing walls. However, suppose these structures are created with moveable partition walls. In that case, there will be no need to demolish these barriers when the time comes to downsize these spaces, saving money and time and preserving the structural integrity of the building.

1.3. Aim of the Study

This research aims to investigate space flexibility in Vocational Training Institute to identify functions that could be integrated into First Technical University, Ibadan in South West, Nigeria.

- i. What type of flexible vocational training institute design is suitable for First Technical University, Ibadan?

1.4. Objectives of the Study

This study will focus on these specific objectives to meet the aim:

- i. To examine the method to adopt for modular principles in vocational training institute design;
- ii. To analyse the properties of flexible space;
- iii. To propose a flexible vocational training institute design for First Technical University, Ibadan.

1.5. Research Questions

- ii. How are modular principles methods adopted into vocational training institute design?
- iii. What are the properties of flexible space?

1.6. Significance of the Study

This study will contribute significantly to designing, planning and partitioning spaces in future VTI design to achieve flexibility and adaptability in interior spaces to maximise existing space use.

1.7. Scope of Study: Target Group

This research is focused on the concept of adaptation and flexibility in the interior spaces within Vocational Training Institutes. In addition, space modularity and the nature of the walling materials used in these centers will also be taken into account, as they affect the level of flexibility available. The various possibilities of combining activities to create flexible spaces are also presented, as are several possible modular dimensions.

1.8 Operational Definition of Terms

An Operational Definition is the definition of a variable in terms of the operations or techniques used to measure or manipulate it. (<https://www3.unisa.ac.za/nicw3vx/page.php?>) The following are the terms used .

- i. Vocational training:** Vocational training refers to institutional programmes or courses that concentrate on the skills needed for a specific job function or trade. Vocational training focuses on procedural knowledge rather than theoretical or declarative knowledge. Education in vocational training prepares students for particular careers while ignoring traditional, unrelated academic subjects. Vocational training, also known as Vocational Education and Training or Career and Technical Education, provides hands-on, job-specific instruction and can lead to certification, a diploma, or even an associate's degree. Students typically need vocational training to prepare for trades such as automotive repair, plumbing, culinary arts, graphic design, fashion design, and welding Davis, J. (2021).
- ii. Institute:** An institute is an organised singular or multi-disciplinary unit to conduct education, research, and/or service activities. Institutes are distinguished by their organisational permanence, programmatic autonomy, and fiscally independent annual operating budget. Additionally, an institute must have active faculty participation and a logical connection to the University's instructional and/or research efforts. The Provost, Vice President for Research and Innovation, or their designee, is in charge of an institute. An institute may be affiliated with one or more centres (Marquette University, n.d.).
- iii. Flexibility:** Flexibility is an clear free range of motion and any feature or vibe that is malleable and adaptable. Flexibility is frequently defined as the amount of change that occurs and the degree of permanence of that change. Flexibility in

architecture refers to being malleable, movable, and multipurpose. It is further subdivided into movable partitions, multi-use spaces such as open-plan offices and high-capacity service voids, and the ability of the room to expand. The concept of flexibility and design enhances adaptation over stagnation, transformation over restriction, and interaction over inhibition. Any built environment should act as a living organism with unique, functional, design, and material flexibilities (Hiran, n.d.).

- iv. **Adaptability:** Adaptability refers to a building's ability to support multiple functions without changing its architecture (Hiran, n.d.). Adaptability refers to a building's ability to accommodate significant change. Change is unavoidable in a structure's social, economic, and physical surroundings, as well as in the demands and expectations of its residents. Everything else being equal, a more adaptable building will be used more efficiently and last longer because it can adjust to changes at a cheaper cost. Additionally, a longer and more efficient building service life may translate into higher environmental performance across the lifetime Estaji, H. (2017).
- v. **Interior Spaces:** Interior space refers to an enclosed part of a public or commercial building, such as an exterior hallway, connecting structure, entrance, or mechanical system used to condition an enclosed space . Interior space is any substantially enclosed space with a roof and a wall or walls that may restrict the free flow of outdoor air.
- vi. **Modularity:** Modularity is a system property that quantifies how easily densely connected compartments within a system can be decoupled into distinct communities or clusters that interact with one another rather than with other communities (Kharrazi, 2019). Modular architecture, also known as modular

design, divides a system into smaller parts known as modules or skids, which can be created independently and then used in different scenarios. A modular system is distinguished by functional partitioning into discrete scalable and reusable modules, the strict use of well-defined modular interfaces, and industry interface standards (Nady, n.d.).

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Chapter Two

Literature Review

2.1. Conceptual Review

Education entails the facilitation of learning and the transmission of knowledge, and the acquisition of skills, values, beliefs, and habits. Accordingly, every individual has the right to education because it allows inhabitants of a country and the world to realise their full potential. According to Renn, O. (2017). it is the foundation for scientific and technological breakthroughs and modernity, and this has therefore caused all nations of the globe to place high importance on it. Education is the light that illuminates the world; without it, the world would be dark Balogun, (2020). Adewuyi, A. P. (2020). avows the existence of sufficient evidence that more excellent qualifications and abilities protect individuals from unemployment. However, with the rising unemployment rate in Nigeria, the emphasis is gradually shifting from tertiary to skill-based education. That typically results in the shift from the acquisition of abstract knowledge and paper certification to focusing primarily on practical knowledge and the ability to apply acquired skills in a real-world setting, (Ogundiran, 2017).

However, technical and vocational education have been regarded as a crucial component in the shifting global economic system. Nevertheless, there are several obstacles to vocational training education in Nigeria and many other nations. Oyebola, Olaposi, & Akarakiri, (2020).

According to Ausubel, Kramer, Shi, & Hackett, (2022). More than half of the world's population is under the age of 25, with nearly a third falling somewhere between the ages of ten and twenty-four. Therefore, it demonstrates that teenagers are the majority and that

their numerical strength, if adequately harnessed or exploited, will significantly contribute to society rather than allowing it to become a significant threat if left to their own devices.

The world is increasingly becoming connected due to technological advancements. Hence, a nation must work hard to achieve employment independence and optimal management of its natural and human resources to generate income and achieve a stable and reliable economy and a place in the global industrialisation network. In the past, and still in some sections of Nigeria today, vocational education or skill was passed down from generation to generation within families. These families were known for particular skills, such as carpentry, tailoring, art and craft, agriculture, etc. It was a family ritual for them to groom their children and pass on this knowledge, expecting them to pass it on to the next generation to maintain the family's identity. However, as time passed, children were no longer required to study the family trade. Instead, they were free to acquire other specific works of their choice under the supervision of competent experts, family missionaries, or colonial masters.

During the colonial period, non-indigenous companies such as Shell, BP, PZ, and UAC began to train artisans among their employees to acquire the skills required for operation in the companies at the time. No examination was conducted to issue a paper certificate because the primary goal was to improve the workers' ability to complete more complex tasks. Early missionaries, on the other hand, constructed schools mainly for evangelism. The early missionaries' operations were characterised by literacy education aimed at converting people and generating clerks and businesses Akintade (2017). Before the current administration, Nigerians viewed Vocational Training School as a low-level, low-brilliant, and less fortunate or second-class citizen education program Agha, Ukommi, Ekpenyong, & Effiong (2020). Where as, in the shifting global economic order,

vocational and technical education has been considered as a critical component of the educational system.

Today's inventive system is shifting toward skill development classes that can assist both children and adults in becoming self-sufficient. (Ogundiran, 2017). Nonetheless, in Nigeria, as in many other nations, vocational training education has numerous problems Oyebola, Olaposi, & Akarakiri, (2020).

2.1.1 Federal Government Involvement in Vocational and Technical Education

Nigeria's Federal government is not only aware of the necessity to harness her human resources by developing her citizens' vocational and technical potentials to close skill gaps and shortages but also of its importance and contributions to the country's riches and pride. Consequently, her national education policy emphasises that "Technical education is the cornerstone of Nigeria's Development". As a follow-up, Human Development Agencies (HDAs) such as the Industrial Training Fund (ITF) were established to provide training to support the Vocational and Technical education system. According to Ellner, M., Schumacher, O., & Hartwig, M. (2018) formal education should be supplemented with more advanced and obviously industrial training. In light of Nigeria's underwhelming educational output, where technical students graduate without acquiring the necessary technical skills, the importance of the ITF cannot be overstated. Given Nigeria's educational system's underwhelming results, where technical students graduate without having acquired the necessary technical skills, the importance of ITF cannot be overstated. The Industrial Training Fund was established in 1971 by Decree No. 47, which is now an Act of Parliament, to promote and encourage the acquisition of skills in industry and commerce in order to create a pool of indigenously trained labor sufficient to meet the needs of the Nigerian economy. The ITF has devised, developed, and executed

different training programs for the nation's teeming workforce, some of which are technically oriented, to fulfil its statutory obligations over the years. It has also built industrial skills training centres where young people can receive training in various technical fields. The Technical Skills Training Programs (TSTP) are designed to fill technical skill shortages and prepare citizens to meet the expanding, complex, and changing demands of globalisation, scientific, and technological advancements Ellner, Schumacher, & Hartwig, (2018) Despite the efforts of the Industrial Training Fund, evidence from many sources suggests that skilled technical labour is still in short supply in several sectors of the Nigerian economy. Despite increasing training efforts, according to the 2009 Industrial Training Fund report, there is a human capital gap in performance across several sectors of the economy. The Nigerian economy has been suffering from an acute shortage of technical personnel, according to the National Board for Technical Education Akanbi (2017). while the Manufacturers Association of Nigeria's Economic Oviawe, J. I., Uwameiye, R., & Uddin, P. S. (2017). emphasised the fact by noting that the manufacturing sector has been facing serious scarcity of skills and other skilled manpower challenges.

In actuality, it appears that the ITF's Technical Skills Training Programs has had little impact on the residents' skill levels. While the ITF's efforts to create Technical Programs are commendable, the impact on trainees must be determined objectively. As a result, the requirement for an evaluation arises Adewumi, S. A. (2018).

2.1.2 Brief History Of Modular Construction

Although modular construction has recently gained popularity, It is not a completely new idea.

Prefabricated homes were transported from New York to California during the nineteenth century as large segments of the population began to migrate west, such as during the Almaguer, T. (2020).

Prefabricated housing was also popular in the first half of the twentieth century, particularly during times of high demand, such as the years following World War II.

Modular construction began to be used for a broader range of project types, including schools and healthcare facilities, in the late 1950s, and it was used to build large scale hotel projects in the 1960s and 1970s.

The Modular Building Institute has published research showing that between 2014 and 2016, the market share of permanent modular construction in the North American building industry increased in a number of areas. Office and administrative (4.86%), commercial and retail (3.53%), and education (3.50%) had the highest market shares in 2016.

The permanent modular construction industry accounted for roughly \$7 billion in construction activity in 2017, and its estimated overall market share in North America increased to about 3.27 percent from 3.18 percent in 2016, according to the Modular Building Institute's 2018 annual industry statistical report, which was based on a survey of 252 modular manufacturing companies.

(Design for modular construction)

2.1.3 Details Of Modular Approach

Prefabricated modular construction components can either be made as

i. non-volumetric components or

ii. volumetric units

Individual, three-dimensional enclosed pieces are prefabricated and assembled on-site to form a single structure in volumetric modular construction.

Volumetric modular construction is commonly used in multiunit residential projects such as hotels, dorms, and apartment complexes.

Each unit may contain one or more modules, depending on its size.

Volumetric features include patient rooms, restroom pods, and individual elevator or stair core parts.

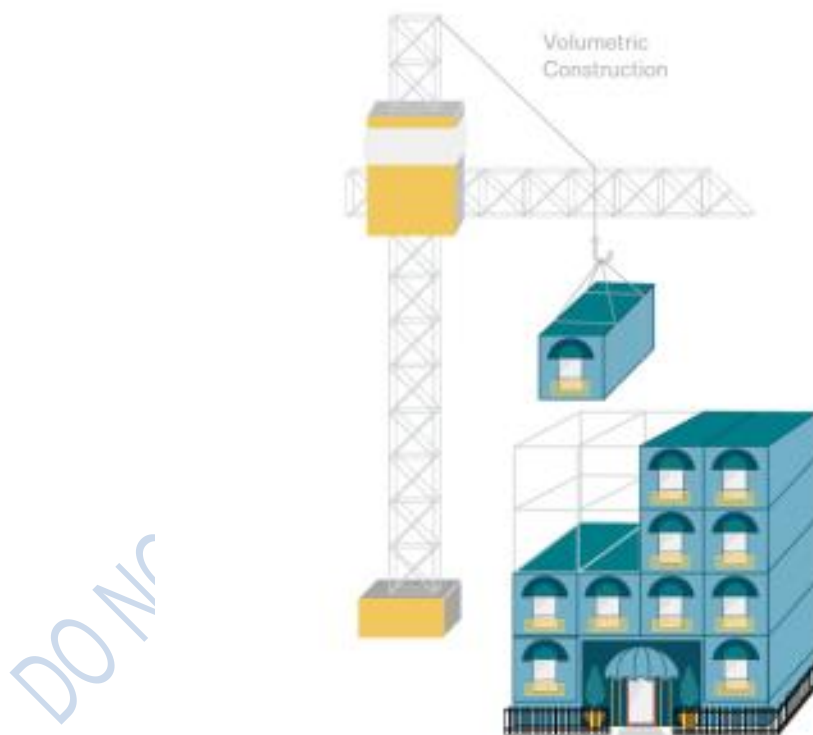


Figure 1: Volumetric construction (Design for Modular Construction)

Non-volumetric modular construction entails off-site prefabrication of building components such as walls, slabs, and roofs (often referred to as sub-assemblies), which are then joined once on-site.

Non-volumetric modular building components frequently used as examples include:

- i. Structural components include beams, frames, and columns
- ii Wall panels and interior partitions
- iii building façade and cladding sections
- iv floor cassettes and planks
- v roof trusses, and wall panels.

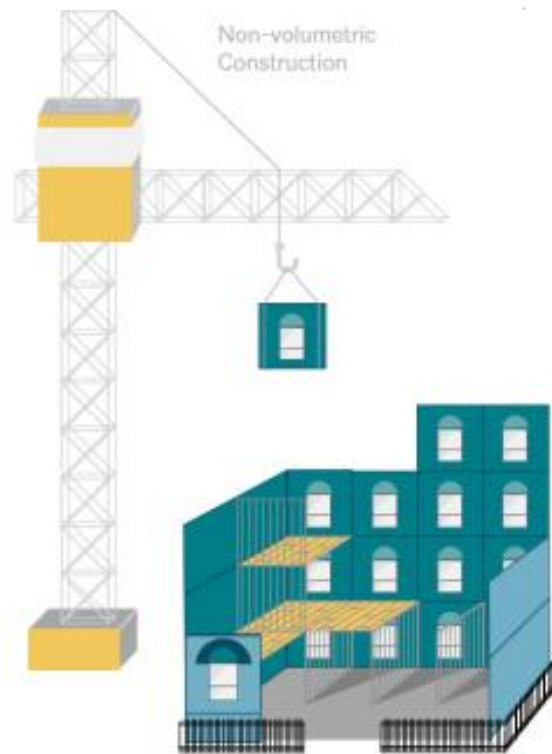


Figure 2: Non-Volumetric construction (Design for Modular Construction)

Depending on the particular needs of the design, program, and/or site, modular projects may be made up of a combination of volumetric and non-volumetric components and may employ a combination of off-site and on-site construction.

For instance, parts required to create expansive holes or spans that may be challenging to produce may be transported more sparingly than volumetric parts, which could lower transport costs, but they need more assembly and sealing work done on site, which could make up for any transport savings.

It should be noted that non-volumetric modular buildings typically take less time and cost less to complete than conventional on-site construction. are frequently built on-site using a modular construction design developed in an off-site facility.

2.1.4 Advantages Of Modular Construction

Aside from being the most effective means of achieving flexibility and adaptability in buildings save for kinetic architecture, there are several advantages to using modular construction in architecture.

However, kinetic architecture is a subset of modular construction that is supported by an automated mechanical system. Other advantages of modular building include:

I. High Quality

Applying the efficiency and controls of highly developed manufacturing processes to building construction produces numerous important advantages in terms of producing high quality output with great precision.

In the monitored production environment, a high level of quality control and consistency is made possible by the use of precise fabrication technologies like CAD/CAM (Computer-Aided Design/Computer-Aided Manufacturing).

When installing delicate high-tech components like fire and security systems or sensor-based programmed environmental controls, this level of quality control is extremely crucial.

A building envelope that is significantly tighter and has fewer air leaks is the result of increased precision in the manufacture of outside wall components.

Depending on the project's architectural shape and program complexity, mass production manufacturing techniques may be applied to gain further economies of scale.

Furthermore, using mass production techniques does not always mean less design flexibility. Project teams and fabricators can collaborate to create a mass customization strategy that makes use of the economies of scale that come with mass production while allowing for variability to satisfy a variety of customer demands and design intents.

The production and storage of building materials in an enclosed facility also means less exposure to the weather, which can result in moisture-related damage during construction, reducing component durability and raising the possibility of mold growth, both of which are dangerous to occupant health.

Furthermore, the monitored manufacturing setting will allow components to reach their maximum strength in comparison to prefabricated concrete component setting.

ii. **Productivity**

When using an off-site approach, labor productivity increases as well.

Inclement weather has less of an impact on a plant crew.

Additionally, a team working in a facility created to provide perfect manufacturing circumstances, equipped with accurate equipment and machinery, can produce higher quality products more quickly.

Off-site construction also implies a more consistent crew and a more controlled workflow that is less susceptible to disruption.

iv. Furthermore, because modular construction necessitates a high level of coordination and collaboration among project team members, it encourages a more integrated process, which can lead to increased productivity during the design and planning stages of the project.

ii **Security**

Additionally, workers are often safer during off-site construction.

Workers aren't exposed to threats from extreme weather or other construction sites, like noise and air quality, because they operate in a controlled atmosphere.

The United States Department of Labor's Bureau of Labor Statistics reports that fatal injury rates in manufacturing are significantly lower than in conventional on-site construction.

Moving construction work to off-site manufacturing facilities could improve the overall culture of construction work by providing workers with more job security and more flexible shifts, as well as increased safety.

Iv **Time Management That Is Effective (Schedule)**

The construction process is much less susceptible to delays caused by inclement weather because the majority of a building is prefabricated in an off-site facility.

This allows for a more consistent schedule. Off-site construction also allows work that would normally need to be sequenced to be completed concurrently. Off-site construction, as opposed to the linear process that typically characterizes traditional on-site construction, allows trades to work concurrently.

According to the Modular Building Institute, if a project is coordinated so that site work and pre-construction engineering are completed concurrently with building component fabrication off-site, the construction schedule can be shortened by 30% to 50%, resulting in dramatic schedule savings.

If true, this is a significant advantage over traditional onsite construction, which requires the foundation to be completed before work on the building can begin. The greater the amount of work that can be completed off-site, the greater the savings as a result of the increased amount of time saved on-site.

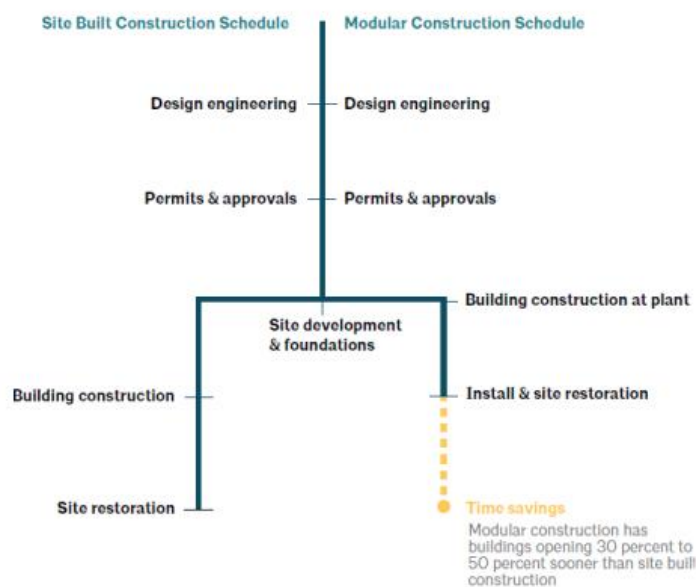
Off-site construction may also reduce supply chain delays because modular manufacturers often have more firmly established connections with a larger network of qualified material suppliers as well as a greater ability to store bulk materials than traditional on-site operations.

Additional savings can be realized by closely coordinating on-site and off-site operations.

Building components should ideally be fabricated, transported, and delivered to the site "just-in-time," based on when the site infrastructure required for their installation is complete, to avoid any additional costs for storage at either the plant or the construction site.

It should be noted that schedule reductions may be affected by the complexity of the project or the level of customization involved.

Although modular construction allows for greater design technical complexity, complex projects with many unique components will require more fabrication and assembly time than projects with more standardized elements. The diagram below contrasts the Modular Construction Schedule with the Site Built Construction Schedule.



v. Value And Cost

With the exception of the expense of interior partitioning, modular construction can be less expensive than on-site building, although this does not always translate into cheaper project costs overall.

However, compared to conventional construction processes, expenses are frequently more predictable.

Modular construction can be used to achieve project affordability and cost control, but it requires more thought in design and thorough planning.

The price of any modular project will vary depending on a number of criteria, just like the price of any conventional project.

When identifying the different individual aspects that will affect the cost of the project and how much, project teams should speak with a modular manufacturer.

Project teams should consult with a modular manufacturer when determining the various specific factors that will impact the cost of the project and to what extent.

Furthermore, the modular manufacturer's expertise is beneficial in determining the most cost-effective method of module transportation.

The transportation cost for any particular modular project, like the fabrication cost, will be determined by a number of variables, such as the trucking distance between the fabrication facility and the job site, as well as the number of trips required..

Most modules will be over-dimensional loads, requiring a special permit to transport on public roads. Depending on the project and location, making the modules as large as possible within regulations and paying for police escort or special routing to reduce the total number of modules and deliveries may be more cost-effective.

The less crane lifts required as a result of this method may help offset the greater cost of larger cranes needed to lift larger components.

All hard and soft costs must be taken into account when comparing the cost of modular construction to other construction methods for a particular project.

Overall, modular construction ought to be viewed as a long-term investment.

Regardless of the use of modular construction should ideally be focused on a clear understanding of the specific benefits the strategy offers and the extent to which these

align with what the project owner values in each particular instance. If implemented correctly, modular construction will prove to be a more cost-effective way to create value in the long run.

Sustainability

Modular construction also can considerably improve the environmental sustainability of a project.

When compared to traditional on-site construction, off-site production of building components, for example, allows for optimal control of material use, resulting in lower material input and waste.

Furthermore, a significant amount of excess material and waste can be managed to capture and reprocessed into the inventory for use on future projects.

In overall, the greater the percentage of a project that is manufactured off-site, the greater this same benefits gained from optimizing material input and reducing waste production.

Project teams can also work with fabricators to select materials and products that have a low environmental impact during extraction, processing, and transportation.

For instance, specifying regionally sourced and responsibly produced materials (such as FSC-certified wood) can decrease the project's personified influences associated with material transportation and natural resource depletion, such as forest degradation.

As building components for several projects can be produced simultaneously at a single plant and transported to construction sites nearly complete, modular construction reduces worker travel and small material deliveries, resulting in significantly lower transportation emissions.

The precision, quality control, and consistency inherent in the off-site production of building envelope components under controlled manufacturing conditions can also reduce the operational energy of modular projects.

Furthermore, because modular construction methods necessitate the completion of fewer seams and joints on-site, it naturally lends itself to achieving exceptionally high levels of air tightness, such as those required by the Passive House Institute quality standard.

A smaller construction footprint and much less site disturbance are generally benefits of modular construction because it requires less space around the building site for workers, truck traffic, and material storage.

The modular construction process is shorter than conventional construction methods, involving fewer workers, less traffic, and less material processing, so there is also less disruption to the nearby community.

Long Life, Loose Fit, And Reusability

Additionally, modular design has the potential for "plug and play" flexibility, which would make it simple to adapt or modify modular buildings over time for different uses. A modular building could be disassembled into pieces that could be redistributed for use in numerous other projects, or it could be disassembled into pieces that could be reused and reassembled elsewhere.

Even if modules are not reused, buildings made of modular components that can be disassembled would be simpler to decommission and remove in a more controlled manner, which would be cleaner and less harmful to the environment than traditional buildings built and demolished.

Buildings made of modular parts that can be disassembled would be easier to decommission and remove in a more controlled manner, which would be cleaner and less damaging to the environment than conventional buildings built and demolished. Even if modules are not reused.

Beams, columns, slabs, and walls are examples of large components that could be given distinctive identifiers that link them to informational databases, allowing these components to be systematically stored and reallocated for use in new projects based on their design capacities.

By creating smaller assemblies and components that are simple to disassemble and separate into different material categories, module recyclability can be increased even further.

To summarize, the continued evolution of modular construction is likely to be fueled by developments in convergent fields like material sciences, manufacturing techniques, and high-performance design and construction practices. making it a preferred option for achieving the "triple bottom line" of social, environmental, and economic goals

2.1.5 Barriers Of Modular Construction

i. Mis-Perceptions

Owners and project teams may find it difficult to feel at ease using modular construction due to a general lack of experience. But as modular construction becomes more prevalent in the building industry, this is probably going to change over time.

Most projects could use any number of modular components, combining modular and traditional construction to produce a hybrid strategy that still offers many of the advantages of modular construction. Those who are unfamiliar with modular construction

may mistakenly believe that it is an all-or-nothing strategy. For example, it may be advantageous for a project to fabricate only the more repetitive, standardized elements off-site while simultaneously building the architecturally unique elements, like the entranceways, elevators, and stairwells, on-site.

Some architects might also think that modular construction restricts their design options or their control, but in reality, it allows for a lot of design freedom and can accommodate a variety of forms and styles thanks to mass customization techniques. The wide range of projects, including the case studies that will be examined in chapter three of this project, that have recently been constructed using modular methods serve as evidence for this. In addition, the possibilities offered by mass customization techniques might eventually enable architects to more precisely tailor the design of manufactured components. Parametric design tools, for instance, have the potential to give architects significantly more control over the formal qualities of modular building components when combined with sophisticated BIM (Building Information Modelling) and the accuracy of computer-aided fabrication technologies.

Additionally, by giving architects more chances to inspect full-scale mock-ups of specially made components, rapid prototyping techniques can encourage more sophisticated and informed iteration.

ii. Differences Compared To Traditional Construction

Some owners and developers might be hesitant to try modular construction due to the various funding models that are frequently used in it. For instance, compared to conventional construction projects that allow for payment in installments, modular projects may need to pay more upfront for technical approval. As compared to conventional projects, ensuring compliance with building codes may expand the scope of

engineering work and increase upfront costs. Because construction time can be drastically reduced, modular construction may also involve a different cash conversion cycle. Owners who switch to modular construction might have to alter their financing plans.

However, as the KPMG Smart Construction report points out, there is potential to reduce overall development financing by using modular construction by speeding up the construction process. The sooner the project turns a profit, the lower the developer's carrying costs will be during construction. Depending on the state in which the project is located and local requirements relating to procurement, there might also be unique challenges to address if a project is publicly funded. This is because modular construction differs significantly from traditional construction in this regard. For instance, a modular project that will be built almost entirely off-site may not follow the typical Regulatory Body schedule of values that would serve as the basis for monthly progress payments. Due to this challenge, some publicly funded projects might not be able to accept payment certifications.

Some trade unions in the construction sector are also opposed to modular approaches. Some claim that modular construction lessens the need for traditional trade labor because it involves a rising level of standardization and industrialization.

However, proponents of modular construction contend that the use of rapidly developing technologies, tools, and techniques in modular construction will instead result in new and more alluring career opportunities in the construction industry, particularly for younger workers.

Others merely draw attention to the fact that off-site building is required to combat the general trend of declining access to skilled labor. Before the full advantages of modular construction are fully realized on a large scale, some contend that the industry as a whole

needs to undergo a cultural shift. Starting to incorporate alternative strategies like modular off-site methods in the curriculum of architecture and construction education programs might be one way to promote such a cultural shift in practice. Ibrahim and Rashidi (2017).

2.1.6 Other Factors To Consider Are

Last but not least, some aspects of modular construction might make it a less desirable option for some projects. Project teams should think about the following when contemplating modular construction as a potential strategy:

- i. It's possible that manufacturers of modular products cannot efficiently produce extremely complex forms.
- ii. Modular construction may take longer to approve and inspect in locations where local authorities are less familiar with off-site fabrication techniques. (However, many states that might have specialized programs in charge of modular off-site construction would avoid this issue)
- iii. Since each module has its own independent walls, floor, and ceiling, modular construction generally produces a bulkier structure when using a volumetric approach. This entails thicker walls and deeper floors than in conventional construction. If not properly taken into account during design, this could have a negative impact on interior living spaces in taller structures by reducing the usable area and volume of interior space, even though it may be advantageous in terms of acoustics, energy efficiency, and thermal comfort.
- iv. Modular construction is not suitable for a structure with very wide clear spans and significantly high open ceilings, like a "big box" store.

Additionally, there are some situations where modular construction is not recommended and where its advantages are unlikely to be fully realized.

For instance, the benefits of off-site fabrication's otherwise faster delivery may be less likely to be realized at construction sites that are easily accessible, situated on affordable land, and located in climates that permit year-round construction work. The potential cost savings offered by an off-site approach may also be less than in locations with more expensive materials and labor if the project is in a location with excellent access to reasonably priced materials and labor.

Nevertheless, environmental advantages that can be obtained by maximizing material usage and directly reusing or recycling scrap in the prefabrication process would still accrue.

Likewise, even in these situations, the duration of disruption to nearby properties and the community at large would be shorter. Ibrahim and Rashidi (2017).

2.1.7 Movable Walls In Interior Partition

Fixed wall construction may become as obsolete as typewriters and carbon copies, according to the director of product and marketing management at Gold Bond Building Products in Atlanta, Georgia. Rapid development and the introduction of computer technologies have compelled businesses to look for more adaptable work environments.

Moveable walls are now taking the place of fixed wall construction, with its apparent reconstruction costs and inconveniences (also known as demountable or relocatable partitions) in advanced countries, and have even gone further to program these walls to be controlled automatically. Many companies have put effort into production of movable walls due to its inevitable advantages and constant market. These walls are designed to

meet standards such as fire resistance, acoustics and aesthetics using several medium such as glass, wood, steel and also some composite materials derived from combination of several materials. The principles of movable walls are to create flexible space. These principles include:

- i. Scaling down and scaling up a space to adapt to change in function

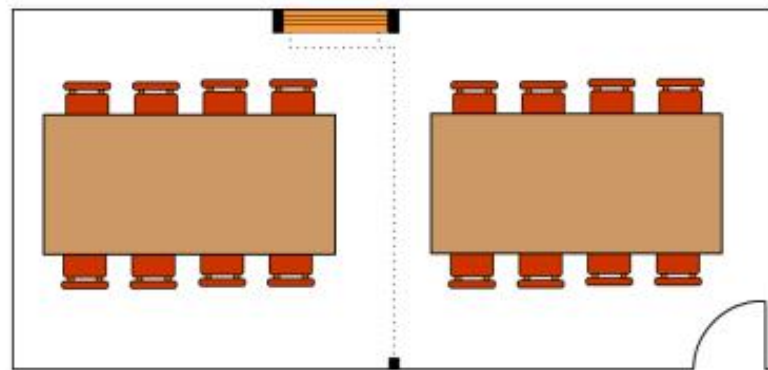


Figure 3: Splitting a space in half (Movable Acoustic Walls for Flexible Space)



Figure 4: Stage 3 (Movable Acoustic Walls for Flexible Space)



Figure 5: Stage 4 (Movable Acoustic Walls for Flexible Space)

ii. Helps to bring the outside – inside the building



Figure 6: (Movable Acoustic Walls for Flexible Space)

iii. Helps to bring in adequate natural lighting into a space (glass modules and steel frame partitioning)



Figure 7: (Movable Acoustic Walls for Flexible Space)

2.1.8 Mode Of Operation

- i. Sliding Wall System: This system is similar to the wall-fold technique but instead of folding, it slides the panels as the name implies



Figure 8: Sliding Wall System (Accordial)

ii. Sky-Fold System: This is a method of folding on stacking the movable acoustic walls vertically into a sky pocket or ceiling pocket until the need arises.



Figure 9: Sky-Fold System (skyfold)

iii. Wall-Fold System: This technique is similar to sky-fold system, but wall-fold system stacks up panels vertically by folding them horizontally like an accordion



Figure 10: Wall-Fold System (Accordial)



Figure 11: Curved movable wall (Hafele)

2.1.9 Packing/Stacking Pattern

This is the arrangement where the movable wall panels are temporarily stored when not in use and can be unloaded as needed. Depending on the manufacturer, these panels can be neatly parked or stacked in various patterns to take up very little space, as shown in the illustrations below.

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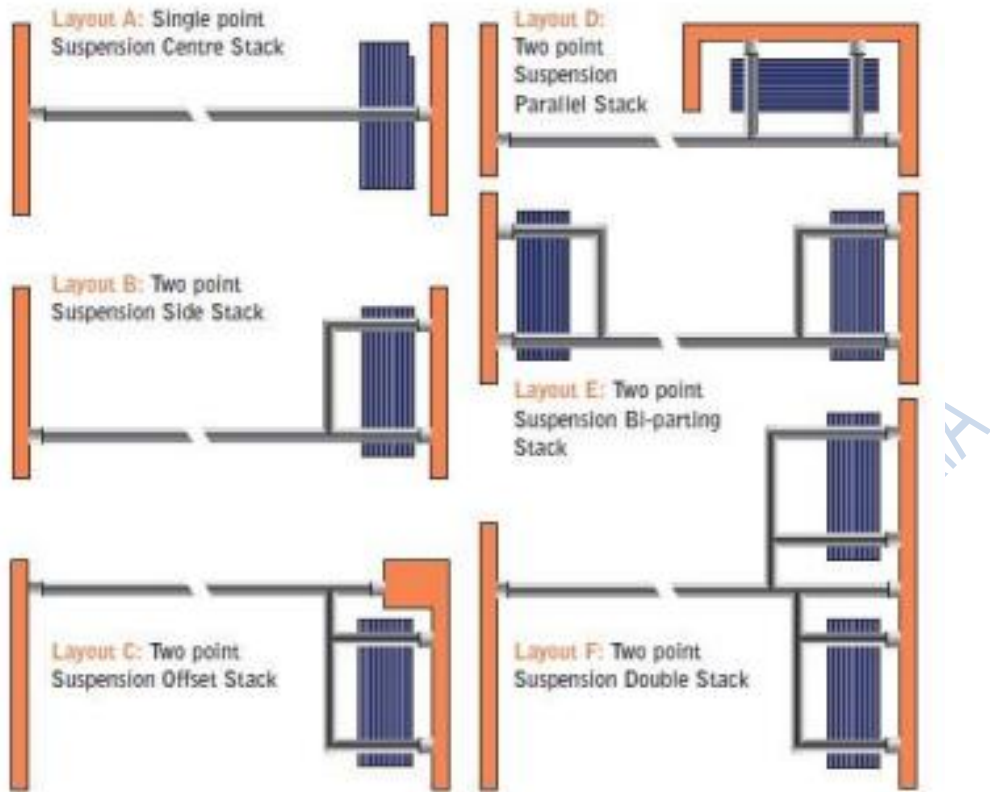


Figure 12: Packing/Stacking Pattern (Moving Walls, Flexible Space Solution)

Typical Easy-to-Operate Stacking System:

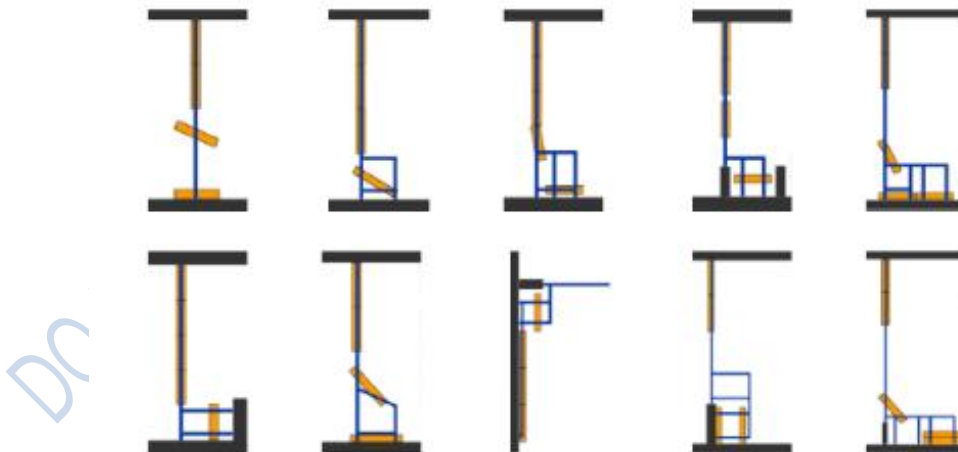


Figure 13: Packing/Stacking Pattern (Movable Acoustic Walls for Flexible Space)

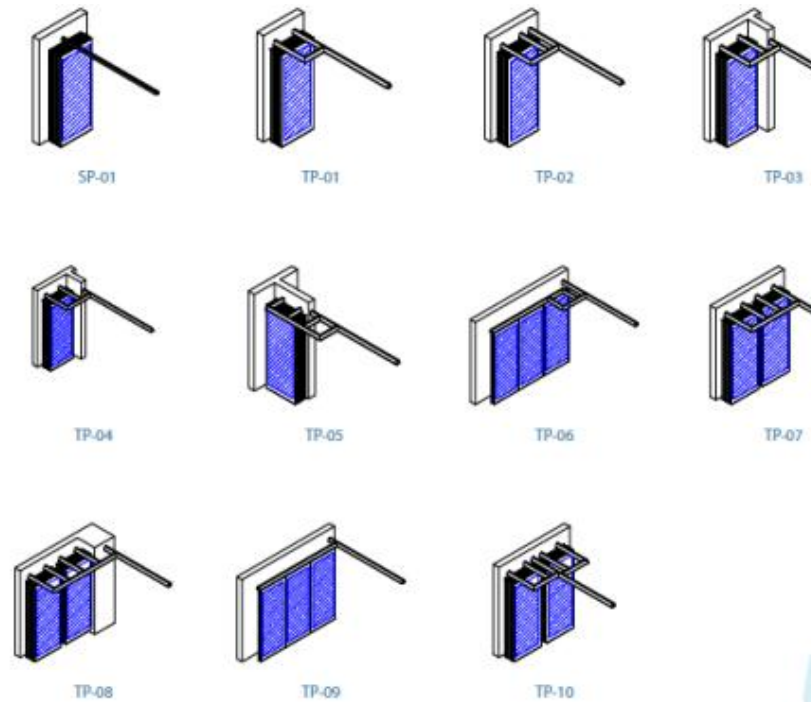


Figure 14: Packing/Stacking Pattern (Divisions)

2.2 Properties Of Movable Partitioning Walls

- i. A variety of materials can be used to create them.
 - I. They are environmentally friendly and have no adverse effects on users.
 - II. They have effective sound insulation properties between 25 and 65 decibels; in fact, they are known as acoustic movable walls.
 - III. They are naturally quite lightweight.
 - IV. They are easily adaptable in terms of layout, style, and form.
 - V. They are inexpensive but require skilled labor to install, making them cost-effective.
 - VI. They come in different thickness and sizes per panel:
 - i. Thickness: 50mm – 100mm
 - ii. Minimum panel width: 650mm

- iii. iii. Maximum panel width: 1250mm, center hung: 850mm, end hung: 700mm
- iv. iv. Maximum clear height: 11mm, also depends on the headroom of the space.
- v. v. Approximate hanging weight: 22 – 47kg/m²



Figure 15: 30 minutes to 1 hour resistant time (Hafele)

2.2.2 The Principle Guiding Modular Design

Modularity is the functional partition of space into mountable and resizable units in modules with measurements that can be divided into threes. The use of flexible and demountable walling units to enclose spaces are two fundamental modular design guidelines, according to Stiles. (2019).

In their 2013 study, Harrison and Hutton propose a reference guide for typical modular sizes for flexible and demountable walling units. This reference guide is shown in Table 1 below. The table lists the various modular workshop sizes as well as the numerous

movable walls that can be employed in these spaces. The last column's areas were calculated by multiplying two modular dimensions. The numerous moveable partitions must follow prefabricated dimensions that are divisible by three, and the workshop spaces

Table 1: Modular room sizes and movable partitions

S/№	Movable Partitions	Modular/Flexible Length / Breadth	Modular/Flexible Area
1	Folding Partitions	3.0m, 3.6m, 4.2m, 4.5m, 4.8m, 5.4m, 6.0m, 6.6m, 7.2m, 7.8m, 8.4m, 9.0m, 9.6m, 10.2m, 10.8m, 11.4m, 12.0m, 15.0m, 18.0m. (Multiples of 3 & 6).	9.0m ² , 10.8m ² , 12.6m ² , 12.96m ² , 13.5m ² , 14.4m ² , 15.12m ² , 16.2m ² , 17.28m ² , 17.64m ² , 18.9m ² , 20.16m ² , 20.25m ² , 21.60m ² , 22.68m ² , 24.30m ² , 25.20m ² , 25.92m ² , 27.0m ² , 28.8m ² , 30.24m ² , 34.56m ² , 51.84m ² , 172.8m ² , 180m ² , 270m ² , 360m ² , 540m ² .
2	Sliding Partitions	3.0m, 3.6m, 4.2m, 4.5m, 4.8m, 5.4m, 6.0m, 6.6m, 7.2m, 7.8m, 8.4m, 9.0m, 9.6m, 10.2m, 10.8m,	9.0m ² , 10.8m ² , 12.6m ² , 12.96m ² , 13.5m ² , 14.4m ² , 15.12m ² , 16.2m ² , 17.28m ² , 17.64m ² , 18.9m ² , 20.16m ² , 20.25m ² , 21.60m ² ,

		11.4m, 12.0m, 15.0m, 18.0m. (Multiples of 3 & 6).	22.68m ² , 24.30m ² , 25.20m ² , 25.92m ² , 27.0m ² , 28.8m ² , 30.24m ² , 34.56m ² , 51.84m ² , 172.8m ² , 180m ² , 270m ² , 360m ² , 540m ² .
3	Flexible Partitions	Any room size	Any room size

Source: Harrison and Hutton (2022)

must be organized in a similar way so that the partitions fit into the spaces.

The modular design grid system in Table 1 may be used during the VTI design phase to create modular spaces that will be surrounded by a variety of movable partitions for a flexible space.

Honyak, M. R. (2018). investigated different types of modular wall arrangements and their premade sizes for active space partition with maximum flexibility. The walling systems are demountable and comprise light weight partitions that can be controlled in a variety of ways. The infill panels are composed of a variety of materials, including glass and aluminum. Sliding partitions, folding partitions, and flexible partitions are examples

Table 2: Types of movable partitions and sizes

S/N ^o	Movable Partitions	Pre-fabricated Sizes (m)	
		Width (m)	Height (m)

of discrete wall units used to create flexible areas, as shown in Table 2.

1	Sliding Partitions	0.6	2.7 (min) 6.0 (max)
		0.75	
		0.9	
		1.2	
		1.25	
2	Folding Partitions	4.5	5.0 (max)
		6.0	
		7.5	
		9.0	
3	Flexible Partitions	Not fixed	5.0 (max)

Source: Adebayo, (2016).

Table 2 summarizes the various widths and heights of various moveable partitions that can be used to enclose spaces.

Only flexible partitions can develop curvilinear forms due to the nature of the operating principle.

On the basis of predetermined dimensions, movable partitions are prefabricated at the factory.

Flexible partitions use a pantographic steel frame, aluminum track systems, and vinyl-coated cloth to create flexible spaces Adedayo, Oyetola, Offiah, & Adebayo (2016).

To enclose spaces, these walls are easily able to be stretched or compressed.

Table 3: Materials used in walls and how flexible they are

S/№	Walling Types	Degree of Flexibility
1	Concrete Wall	Non-flexible
2	Sandcrete Wall	Non-flexible
3	Curtain Wall	Non-flexible
4	Cavity Wall	Non-flexible
5	Fixed Partition	Partially-flexible
6	Movable Partition	Flexible

Source: Ernst and Neufert (2012)



Figure 1: Sliding partitions enclosing a space. **Source:** Corky (2011)

The study also looked into the various types of walling utilised to enclose spaces and their degree of flexibility (see Table 3 above). As shown in Figure 1 below, movable partitions are flexible because their operating principles allow for change and diversity in the sizes of the

Figure 1 depicts an interior room with sliding walls. At both the ground and ceiling levels, the operating principle is based on a horizontal track system. The panels glide easily along the tracks and can be stacked close together for suitable acoustic and heat insulation. The panels are composed of aluminum composite panels, and the tracing system and frames are built of aluminum and stainless steel.

2.2.3 The Concept of Flexible Space Design

The ability to adapt to new, varied, or changing requirements by moving pieces or joints has been termed as flexibility. When architects use the phrase "flexibility," according to Banham, (2022). they frequently distinguish between physical elements intrinsic to buildings and abstract social influences influencing building design. In this example, physical flexibility refers to a space's ability to adapt to specific practices or activities, such as supporting the mobility needs of users. This form of physical flexibility is represented by non-fixed components such as moveable equipment and walls, re-configurable building rooms or spaces, and passageways. In the context of abstract flexibility, however, flexibility refers to a building's ability to adapt to unforeseen modifications such as demographic shifts, community requirements, or legislative obligations Veletsianos, & Houlden, (2020)

Flexibility can also be defined as the ability for spaces to be used in various ways without affecting the structure's fabric. Finally, it can also be described as a building's ability to adapt to constantly changing environmental requirements and conditions.

Flexibility is becoming increasingly relevant and indispensable because it is an indicator of adaptability. According to architecture literature, an essential attribute of a sustainable structure is its ability to adjust to changing requirements and last the test of time. For example, John Habraken, in his description of open construction, noted that the constructed environment is the product of an endlessly developing, never-ending design process in which the environment transforms part by component (Marinovic, G. I. 2022). Therefore, only the long-term effect of established flexibility measures can be assessed. As a result, the difficulty comes in estimating the proper amount and character of the steps to be applied (Wang, Gao, & Chen, 2018).

There is no need for change as long as a building fulfils the needs of its users, but when those needs change, the building must adapt. And in this scenario, flexibility means adjusting to future advancements and user needs in a short amount of time with the least amount of effort and resources while causing minimal or no damage to the components or modules that make up the interior space. Therefore, according to Rockow (2020), there is a need to explore different scenarios throughout the planning phase to forecast space, building demands, and their implications.

2.2.4 Flexible Properties of Space

Iglesias, Ares, González & Rosales (2020). flexible qualities of space are properties of a space that, when considered in the design, can assist in achieving a more flexible building.

These characteristics are:

i. **Versatility:** This is the property of space that permits it to be used for various purposes. Auditoriums, common rooms, and multipurpose spaces are adaptable spaces, but they also risk homogeneity (Wang, Gao, & Chen, 2018). Because all places allow for certain activities and movements, identifying generic spaces that lack open cues for specific

usage necessitates extra work. For example, when using an auditorium for an exhibition, furniture must be rearranged or removed to accommodate the desired activity. In doing this, furniture must be moveable rather than fixed. Because these adjustments do not permanently alter the space, it can easily transition between the start-state and end-state. The container's overall size and shape do not vary as the function does.

ii **Convertibility:** This refers to a space's flexibility to support shifting functions with some construction or reconstruction, as the case may be. Predicting future needs minimises construction costs and time. Modern office structures or spaces are frequently used as examples for this kind of adaptable space because they have a core with HVAC (Heating, Ventilation, and Air Conditioning), electrical, and communication systems that is surrounded by a shell with readily adaptable space for a variety of activities or programs. Kohlhepp, Harb, Wolisz, Waczowicz, Müller, & Hagenmeyer, (2019) Spaces created for convertibility necessitate foresight into the future: they should be structurally modular and open-ended, with a design that can be re-designed by others. As a result, the rooms can be transformed with less building effort, decreased time, and lower cost once the facility recognises the need.

iii. **Fluidity:** The free movement of elements such as sound, air, and sight or visual comfort about the individual inhabitants of the spaces is considered in this element. Open spaces encourage fluidity but may also be a major impediment to fluidity if they appear oppressive in their expansiveness or overemphasised in size and proportion. In classrooms, for example, strategically positioned displays can increase intimacy while piquing interest in the environment that flows around the screen Cahalan,(2019). The area becomes more engaging and less overwhelming as a result. A sense of fluidity and connectedness between rooms can also be enhanced by strategically placed windows Wang, Gao, & Chen,(2018).

vi. **Modifiability:** This particular aspect of the environment promotes aggressive space appropriation and manipulation. For the purpose of creating environments that may be swiftly rearranged, mobile elements including walls, partitions, furniture, and equipment are used.

Highly adjustable settings promote creative experimentation to match the needs of various people with the space and subject matter. When constructing such spaces, it is important to consider a number of structural dependencies, such ceiling layout for lighting and air circulation, floor materials for ease of moving partitions, and so forth. Cahalan,(2019).

v. **Scalability:** The ability of space to expand and compress is one of its properties. Building expansion may necessitate the addition of components to suit the demands of expanded functions - auditoriums, service areas, storage rooms, etc. are examples of such spaces. Spaces that are compact or well-designed, such as corridors and offices, may be efficient in the short term, but eventual increase in the activities that take place in them may be difficult or impossible to achieve. In the case of contraction, however, gaps must be reduced. Buildings should be able to be temporarily reconfigured into discrete and smaller rooms for various uses that demand smaller spaces Claux,(2019).

2.2.4 Typology of Flexibility in Architecture

The Fraunh of Institute's views, which were reinforced by typology-based building evaluation, identified four (4) basic categories of building flexibility. These are:

- i. **Internal Flexibility:** This determines a building's adaptability, or the extent to which adjustments to an existing structure's interior spaces are achievable.

Considering the risks and time constraints, as well as how the extension will affect the structure.

- ii. **Exterior Flexibility:** This refers to the process of studying and classifying the placement and structural qualities of building additions and modifications.
- iii. **Flexibility of Use:** This entails examining how it responds to changes in use and building flexibility.
- iv. **Planning Flexibility:** This refers to the features that govern whether and how a structure reacts throughout the planning and construction phases. It also looks into which measures can be put in place during the planning phase to provide for maximum flexibility during a building's operational period for the least amount of money and work (Cowee, 2009).

2.2.5 Concepts for Flexible Design in Educational Buildings

The belief that the design of constructed places impacts the behaviors and activities of humans within such spaces is at the heart of educational architecture literature. These spaces, to some extent, embody the designers' teaching ideals. Built pedagogies work on a scale that ranges from discipline to autonomy. They can limit learning opportunities on the disciplinary side by prohibiting particular movements or flows. A desk that is permanently (bolted) to the ground, for example, makes flexible clarifications of spatial use demanding and imposes guidelines for the used of space should arrange . Open classrooms, on the other hand, welcome and nearly demand that students modify the spaces to fit their own needs (Torin, 2002). All environments, like technology, are underdetermined in the sense that they provide communications to users about suitable behavior but leave room for individual interpretation.

Architects can create flexible educational environments in a variety of ways to meet technological advances and future needs. Using participatory design, architects can work

with users to determine what kinds of learning spaces are desired and why, and then design those spaces in accordance. Alternatively, architects can imagine likely future learning activities and then design space to actualize those imaginations (Valiant, 1995). As a result, architects and planners are being confronted with the necessity to construct flexible spaces in order to facilitate learning. Designers must conceive places that go beyond functionality and comfort when assessing designs using the flexible standards of fluidity, versatility, convertibility, scalability, and modifiability.

Because it understands the policy of built trainings and then aims to enhance classroom practices, the exercise of transferring flexibility into built form becomes an ethically accountable act (Torin, 2002). According to Ponti's (2005) study of flexibility in the learning environment, flexibility in the design of schools has advantages in terms of maximising space utilisation. The Italian Cisem research on Flexible Didactic Module Prototype (DM) project began with the creation of a modular learning environment with a connective corridor and a basic module measuring 7.2meters by 7.2meters. Later, the didactic model was modified to incorporate small, medium, and large groups. He achieved this by closing some common doors and collapsing some mobile partitions to create built spaces that can improve learning capacity (Loor, 2002).

In the area of flexibility a number of studies have been investigated namely:

- i. Making the most of available space by using transformable furniture that allows one set of furniture to be folded away while another is pulled out.
- ii. The creation of non-functional areas that can be used for household or non-domestic purposes and can alter over time.
- iii. Sliding doors: In the study's "work/home facility", sliding doors were utilised to seal off private portions; when the building is only used for domestic purposes,

these doors are opened, transforming the spaces into residences that may be used in a variety of ways. A fold-down desk replaces the multifold-up bed, resulting in multi-functional space utilisation.

Furthermore, by removing features that make a room particular to a particular function, like kitchen units, the spaces could be changed from domestic to non-domestic.

These work-homes were also created with adaptability in mind. They were physically stiff over two storeys, and no internal support from floors or internal walls is required. This implied that they can be constructed without internal partitions or with internal walls and flooring that can be easily removed when needed. There are no loads bearing components in any of the interior elements.

2.2.6 Concepts of Flexible Design in Healthcare Design

The principle of flexibility in design has also been used extensively in the design of healthcare facilities.

When it comes to hospital architecture, flexibility refers to the facility's ability to adapt to "new, different, or changing requirements. Because functions change so quickly, designers should no longer strive for the best possible fit between structure and function. The real requirement is to create a structure that will accommodate the least amount of change in functions, rather than one that will best suit a given purpose. (2014, Victoria). Llewelyn-Davies Weeks incorporated a linear hospital into the design of Northwick Park Hospital and Clinical Research Centre in London, which serves as a backbone to which ribs may be connected with relative ease. It is the earliest example of postwar hospital planning with planned indeterminacy (Miller et al, 2002). This allowed the hospital and

research divisions to be built independently of one another and then adjusted or enlarged. Construction took place in segments over a nine-year period, with additions and changes to the initial brief undertaken without affecting the original structural design (Varawalla, 2004).

Buildings such as huge hospital construction projects, According to Richard De Neufville, major construction projects like hospitals are planned 10 to 20 years in advance and are often built to last more than 40 years. Demands on infrastructure are expected to alter dramatically throughout this time.

The administration and financing of healthcare services, demographic changes, new medical technology, rules and regulations, and evolving epidemiological trends can all lead to shifting demands. According to Miller and Swenson (2002), hospital structures are frequently required to support several of these changes due to high levels of uncertainty, changing technology, and treatment procedures. As a result, hospital design must include flexibility. The ability to use flexibility options is determined both by an organisation's ability to be flexible and its commitment to being flexible, according to Walker and Shen (2002), who researched flexibility in a hospital building project. The presence or absence of interstitial or segmented areas as midway service levels between principal floors has been linked to hospital building flexibility.

Recently, the idea of hospital building flexibility has been broadened and now includes a number of ideas and approaches.

Wright et al. (2009) assert that a hospital's flexibility should take into account a variety of factors, including its physical attributes, its connections to other parts of the healthcare system and to supporting infrastructure like transportation links, as well as its financial status.

According to Richard De Neufville and colleagues, flexible design in hospital buildings can be a matter of structural foundations that permit the addition of additional floors on top of existing buildings, areas that are built but not equipped with medical equipment, or functional rooms that may be modified for medical purposes other than their original use (2008).

Standardized equipment, single-bed clusters, standard room categories, and flexibility in management, organization, and facility use are other flexible design components.

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Chapter Three

Methodology

3.1. Preamble

This study will use a case study method to examine and analyse similar structures in order to learn how to incorporate modular flexibility and adaptability into the proposed design, as well as a literature review of existing research works, both published and unpublished, seminars, academic journals, textbooks, and other professional documents that may be relevant to the subject matter, and while maximising the utilisation of space in the workplace.

3.2. Research Instruments

3.2.1. Field Survey

A field survey was used to verify information that couldn't be gathered any other way due to the research nature. To this effect, all the selected case studies were visited. Field visits were supported by photographs taken and comprehensive notes, giving clear and detailed information pertaining their physical presence and spatial relativities.

3.2.2. Internet sources

The study was supplemented by data retrieved from the internet. The information retrieved were subjected to a carefully planned checklist for the international case studies.

3.2.3. Interview of relevant authorities

The relevant authorities present on site upon visitation to the facility were orally interviewed. In each of the selected case studies centers, questions well asked and modified based on peculiarities. Questions asked were open ended and receptive

questions, and were decided or prepared in advanced on what areas to cover. This enabled both the researcher and interviewees to discuss within context the history and relevant information.

3.2.4. Checklist

A check list is a type of informative task aid that is intended to make up for probable limitations in human memory and attention in order to decrease failure. It aids in ensuring accuracy and thoroughness when performing a task. It serves as a reminder list of things that must be done, things to accomplish, or things to think about.

3.2.5. Photographs

To complement the notes made during the tour and for documentation, pictures were taken.

The images served as an important source of visual information on the case for viewers from outside the area. In order to demonstrate the characteristics of bioclimatic architecture the examples possessed as well as the extent to which they were applied, images of the pertinent locations were obtained.

3.2.6. Sketches

During the field survey, sketches were prepared to illustrate the chosen case studies. In order to explain the research, these sketches were thought to be crucial for developing an opinion on the actual location and spatial arrangement of the case studies.

3.2.7. Notes

This method of gathering data was chosen to support the information that was mentioned in the interview and what was seen during the field survey. As the investigation progressed, thorough notes were made as a continuous record of what was happening.

3.2.8 Procedure for Data Collection

The data collection was made through various tool of data collection. Entirely designated case studies except for the international case studies were visited by the researcher for field survey, interviews were conducted, photographs were taken, notes and sketches were formed; while international case studies were analyzed through careful observation of information obtained from the internet.

However, in cases where there was no documentation available for the architectural drawings, the buildings were surveyed and the drawings were prepared by the researcher through sketches, photographs and notes. All photographs were taken either by the author or with help of colleagues. Photographs of relevant areas of the case studies were taken in order to highlight the observed the flexibility and adaptability characteristics of the facilities, and also functional spaces required.

Site visits were used to gather data, guided by a field guide, in search of architectural, spatial, and site components that would support the study's goals. Interviews with pertinent staff or administration were conducted in addition to the observations.

3.2.9 Case Studies Analysis

An architectural case study enables the researcher to evaluate an existing design critically in order to identify both its virtues and any flaws that should be carefully avoided while creating the new design.

In order to comprehend how to combine modular flexibility and adaptability in the design of a vocational training institute, this research work utilises a case study methodology in investigating and analysing structures that are comparable to one another. The case

studies conducted help the researcher become aware of potential problems and how they were successfully resolved in earlier or similar designs.

Five (5) buildings were chosen and qualitatively examined to act as a model for the new design. In addition, literature reviews of recent studies—both published and unpublished—from academic journals, textbooks, seminars, and other sources that might be useful for the topic were used.

3.3.0 List of Selected Case Studies

- i. Women In Agriculture And Youth Empowerment Foundation (WAYE Foundation) (Local)
- ii. Herningsholm Vocational School Herning, Denmark. (International)
- iii. Government Technical College Bukuru (BUTECH), Jos, Figure au State. (Local)
- iv. Gebze Industrial Vocational High School, Turkey (International)
- v. The Polytechnic Ibadan, Vocational Skill Entrepreneurship Study Center (VSESC), Oyo State (Local)

3.3.1. Case Study 1 (Local)

Case Study Two: Women in Agriculture and Youth Empowerment Foundation (WAYE Foundation)

Location: Doi Village, Du District, Jos South Local Government Area, Figure au State.

Architect: Haro Zego

Client: Her Excellency Mrs. Ngo Talatu Jang

Building Type: Institutional/Commercial Building

Date Built: 2009

Structural System: Load-bearing wall structure

Brief Background

The Women in Agriculture and Youth Empowerment Foundation was established in 2009 by the Her Excellency Mrs. H. Jang, wife of the Former Executive Governor of Figure au State. It is located in Doi Village, Du District, Jos South local Government area of Figure au State. The foundation admits women between the ages of 15 - 34 years willing to acquire skills in any vocation of their choice regardless of their secondary school background. It aimed at empowering the less privileged. There are about 130 trainees and 15 staff. Director and assistant director head the foundation.

Departments

The foundation has three departments presently. The departments are as follows:

- i. Catering
- ii. Information and Communication
- iii. Fabric dyeing and Hairdressing

Facilities

The school facilities are divided into four sections, namely:

- i. Administrative Block;
- ii. Workshops/Practical Section;
- iii. Accommodation (trainees);
- iv. Multipurpose hall and a restaurant;



Figure 17: Aerial view of Women in Agriculture and Youth Empowerment Development Foundation. **Source:** Google Earth (2022)

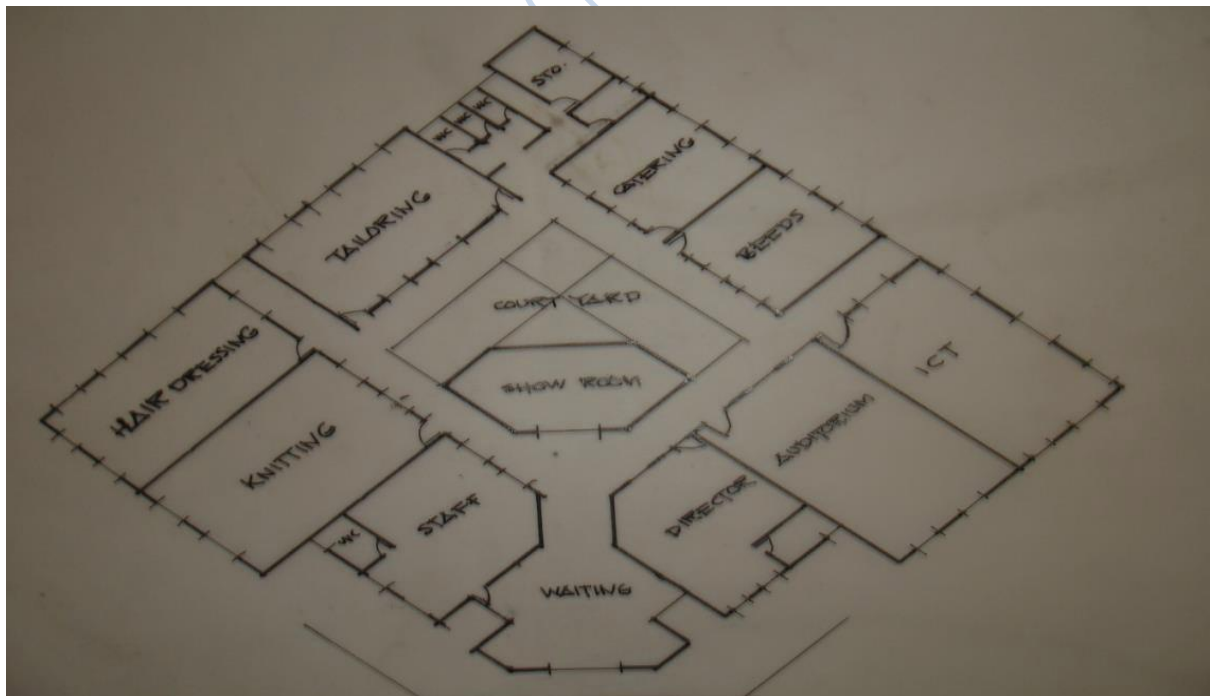


Figure 18: Floor plan. **Source:** Ministry of Works and Housing, Jos, Figure au State.



Figure 19: Approach View. **Source:** Researcher's fieldwork (2022)



Figure 20: Side View. **Source:** Researcher's fieldwork (2022)



Figure 21: Courtyard. **Source:** Researcher's fieldwork (2022)

Variables

vi. **Architectural Style:** Plain geometric forms were employed on plans and elevations. A careful massing of these forms makes up the plan and the elevations. This makes the facility a simple modernist style.

vii. **Scope of facility:** The facilities include the administrative section, workshops, multipurpose hall, restaurant, and accommodation for boarding trainees.

viii. **Construction technology:** The construction technique uses the load-bearing walls structural system whereby all loads are transferred to the soil through the walls with a hip/gable exposed roof. The walls are of bricks and sandcrete block rendered with cement sand mortar.

ix. **Building materials:** The major materials used for the construction of this facility are concrete, sandcrete block, bricks, aluminum roofing sheets, glass, steel, and timber roof members.

x. **Flexibility:** All partition walls are not movable, and load-bearing walls, any attempt to relocate or move the walls will utter the structural stability of the building.

Table 4: Case study one summary of findings.

Variables	Adequate (√)	In-Adequate (X)	Not Available (0)
Architectural Form	√		
Scope of Facility		X	
Construction Technology	√		
Building Material	√		
Flexibility and Adaptability			0

3.3.2. Case Study 2 (International)

Case Study Two: Herningsholm Vocational School (HVS)

Location: Herning Denmark

Architect: C.F. Moller

Date Built: 2014

Site Area: 4,700m²

Brief Background

Within the current campus cluster of academic buildings, the new HERNINGSHOLM Vocational School stakes a claim for itself as a standalone building. The school is constructed both from the inside out with a focus on creating the best study and learning environments and from the outside in with consideration for the surrounding area, where warm urban areas offer opportunities for outdoor work and instruction.

Spatial Organisation

The study spaces in the building are arranged around a unified common area that also doubles as a flexible learning space. All of the school's learning areas have direct access to the common area because they are organized 2 and 2 together. The classroom rooms were created with a variety of flexible, modern learning ideas in mind and are intended for widespread use in the building. The rooms are improved by built-in seating/study niches in the facade, which also encourage other, less conventional usage. For a variety of educational scenarios, mobile furnishings can swiftly modify the learning environment. The common study spaces also provide a variety of physical environments in which to work, ranging from double-height rooms facing the garden, which are suitable for workshop-like uses, to a student café space for informal student gatherings, to dedicated study corners with quieter and more intimate character - and each individual learning space is designed for a variety of setups and spatial uses.

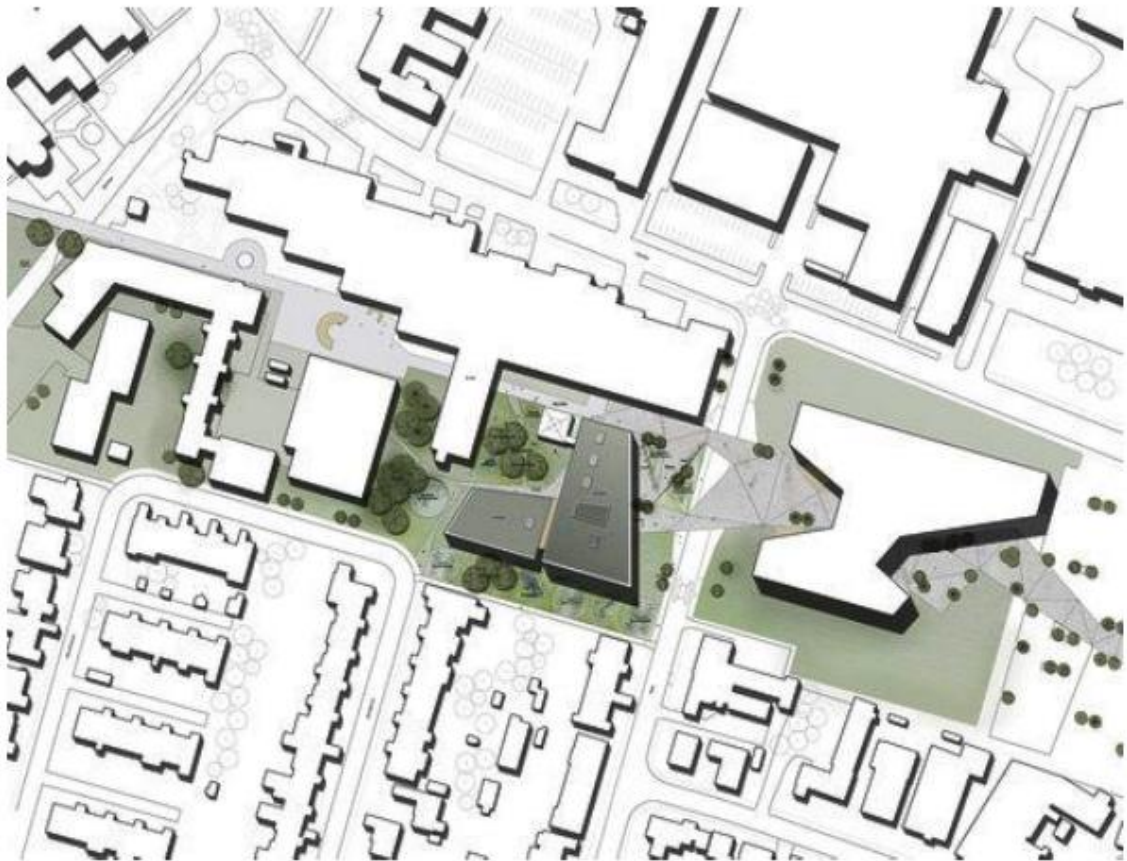


Figure 22: Aerial View showing Herningsholm Vocational School.
archdaily.com (2022)

Source:



Figure 23: Aerial view showing Herningsholm vocational school. **Source:** archdaily.com (2022)

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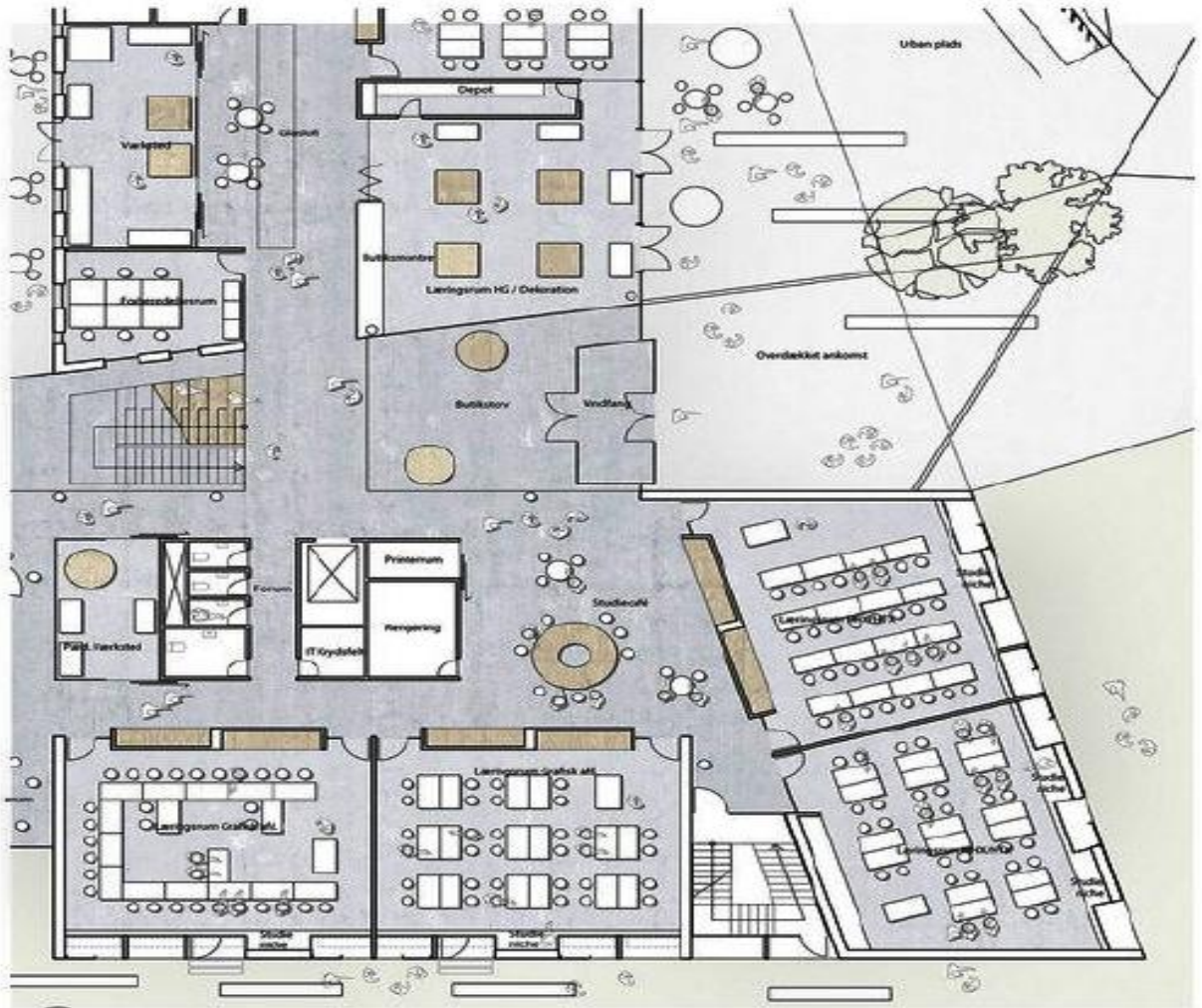


Figure 24: Detailed Floor Plan **Source:** archdaily.com (2022)

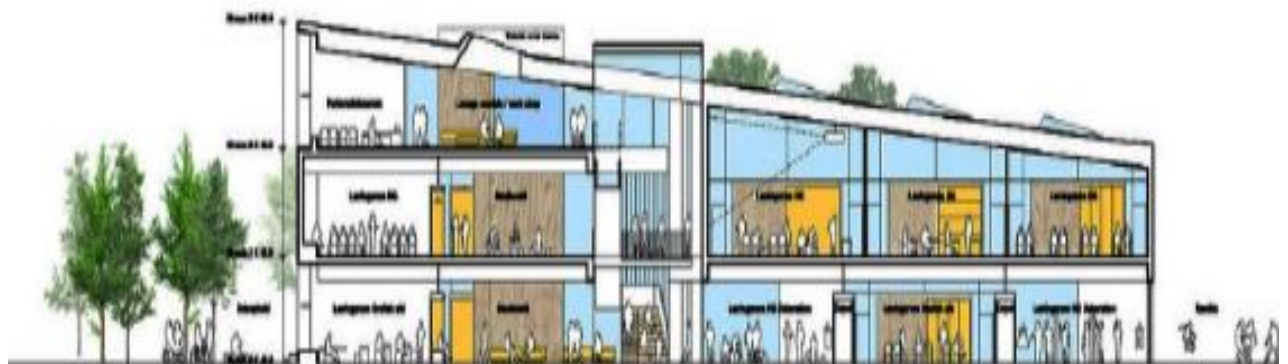


Figure 25: Sectional view of the building. **Source:** archdaily.com (2022)



Figure 26: View showing the main entrance into the school. **Source:** archdaily.com (2022)



Figure 27: Interior view of the building's common space. **Source:** archdaily.com (2022)



Figure 28: Interior view of the building showing non load-bearing demountable walls

Source: archdaily.com (2022)

Variables

- i. Architectural Style:** Both the plan and the elevations used simple geometric forms. The elevations and the plan are constructed by carefully massing these forms. This gives the building a straightforward modernist look.
- ii. Facility Scope:** The facilities include staff offices, classrooms, laboratories, workshops, a common study area, a cafe, a plaza, a study garden, and an outdoor study area in the front garden.
- iii. The technology used in construction:** The classic post and lintel system is the foundation for the construction method. It features free-standing concrete

construction with a flat roof hidden by parapet walls. The walls are made of glass curtain walls, concrete, and sandcrete blocks.

- iv. **Construction materials:** Concrete, sandcrete blocks, glass, pre-fabricated fiber cement panels, aluminum, steel, and bronze-anodized are the main ones employed.
- v. **Flexibility and Adaptability:** All partition walls are demountable and non-load-bearing, so moving or relocating them to create a larger or smaller area due to a change in the space's function or advancement will not have an impact on the building's structural stability.

Table 5: Case study two summary of findings.

Variable	Adequate (√)	In-Adequate (X)	Not Available (0)
Architectural Form	√		
Scope of Facility		X	
Construction Technology	√		
Building Material	√		
Flexibility and Adaptability	√		

3.3.3. Case Study 3 (Local)

Case Study Three: Government Technical College Bukuru (BUTECH), Figure au State, Nigeria

Location: Bukuru, Kuru District, Vom road, Jos South Local Government Area, Figure au State.

Architect: Anonymous

Date Built: 1954

Structural System: Load-bearing wall structure

Brief Background

Through the ministry of education, the Figure au state government founded Technical College Bukuru in 1953. It is situated along Vom road, Bukuru, Figure au State's Jos South local government area. The school has 54 staff members and about 1200 students.

Departments

The school has fourteen departments presently. The departments are as follows:

- i. Building, Agricultural Mechanization
- ii. Motor Mechanic
- iii. Radio and Television
- iv. Electrical Installation
- v. Refrigeration/Air Conditioning
- vi. Mechanical Engineering Craft
- vii. Fabrication and Welding
- viii. Furniture Craft
- ix. Plumbing and pile fitting
- x. Carpentry and joinery
- xi. Hair dressing



Figure 29: Aerial view of Government Technical College Bukuru. **Source:** Google Earth (2022)

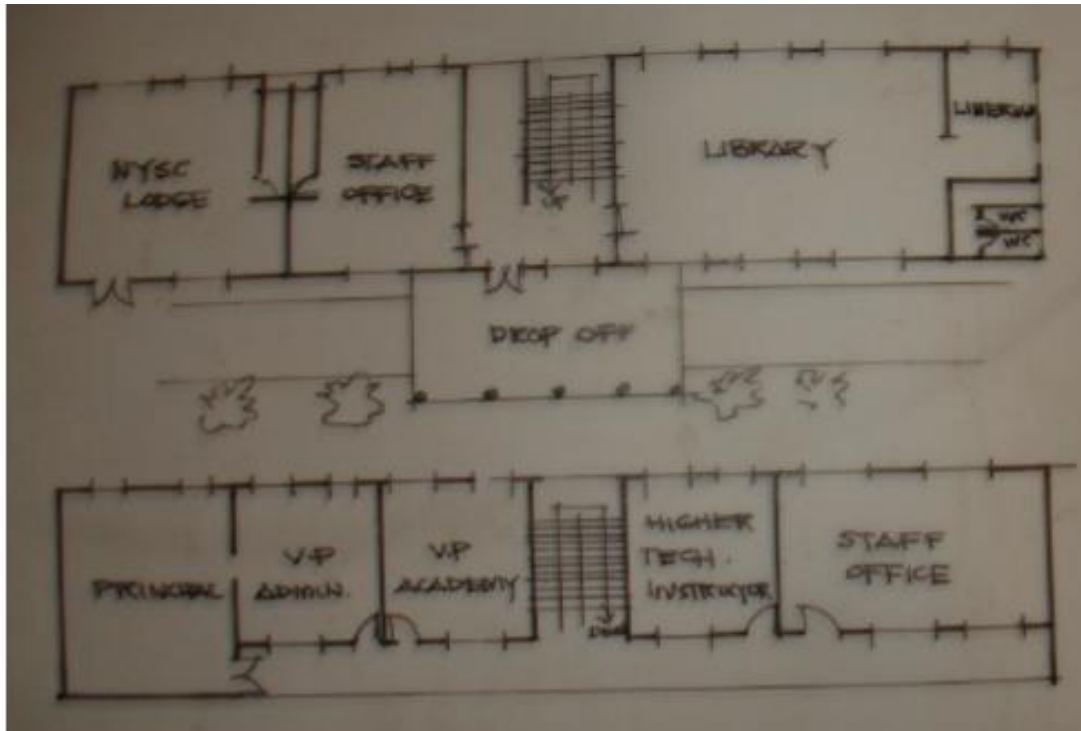


Figure 30: Floor plan **Source:** Google Search Engine (2022)



Figure 31: Figure 18: View showing the Administrative block. **Source:** Researcher's fieldwork (2022)



Figure 32: View showing general metal work workshop. **Source:** Researcher's fieldwork (2022)



Figure 33: Interior view showing woodwork workshop. **Source:** Researcher's fieldwork (2022)

Variables

- i. **Architectural Style:** Both the plan and the elevations used simple geometric forms. The elevations and the plan are constructed by carefully massing these forms. This gives the building a straightforward modernist look.
- ii. **The facilities' scope:** includes the main office, vice principal's administrative and academic office, staff office, other offices, classroom blocks, drawing studios, laboratories, workshops, assembly hall, staff quarters, dorm rooms for students, dining hall, and recreation area.
- iii. **Construction technology:** The load-bearing walls structural system, which transfers all loads to the soil through the walls with a hip/gable exposed roof, is used in construction. Bricks and sandcrete blocks rendered with sand mortar make up the walls.
- iv. **Construction materials:** Concrete, sandcrete blocks, bricks, aluminum roofing sheets, glass, steel, and timber roof components are the main materials used to build this facility.
- v. **Flexibility:** Since load-bearing and partition walls are not fully movable, doing so would compromise the building's structural stability.

Table 6: Case study three summary of findings.

Variable	Adequate (√)	In-Adequate (X)	Not Available (0)
Architectural Form	√		
Scope of Facility	√		

Construction Technology		X	
Building Material	√		
Flexibility and Adaptability			0

3.3.4. Case Study 4 (International)

Case Study Four: Gebze Industrial Vocational High School

Location: Gebze, Kocaeli, Turkey

Architect: Norm Mimarlik

Date built: 2015

Architectural style: Modernist Style

Site area: 12,000 m²

Spatial Organisation

When approaching the city center, the massive plastic arrangement of the building is in tune with the surrounding. Upon the approach of the structure, It can be observed that the entrance canopy establishes a distinct scale that is human-centered. The main entrance and canopy create an interface that leads to the central courtyard.

Façades made of bare concrete and opaque polycarbonate panels draw references to the design's simple and "technical" parts, highlighting the tectonic nature of architectural materials.

photovoltaic (PV) panels on the building's south and south-west sides, ferroconcrete and steel composite structures, heat-resistant joints for movable surfaces.

Variables

- i. **Architectural Style:** Both the plan and the elevations used simple geometric forms. The elevations and the plan are **constructed** by carefully massing these forms. This gives the building a straightforward modernist look.
- ii. **Facility Scope:** The facilities include the Head's office, various staff offices, classrooms, laboratories, workshops, a common study area, a cafe, a plaza, a study garden, and an outdoor study area in the front garden.
- iii. **Construction technology:** based on the conventional post and lintel system is used in this project. It features free-standing concrete construction with a flat roof hidden by parapet walls. The walls are made of glass curtain walls, concrete, and sandcrete blocks.
- iv. **Construction materials:** Glass, pre-fabricated fiber cement panels, concrete, sandcrete blocks, aluminum, steel, and bronze-anodized perforated shutters are the main ones employed.
- v. **Flexibility and Adaptability:** All partition walls are demountable and non-load-bearing, moving or relocating them to make room for an increase in size or a decrease in requirement for space owing to advances will not affect the building's structural stability.

Table 7: Case study four summary of findings.

Variable	Adequate (√)	In-Adequate (X)	Not Available (0)
Architectural Form	√		



Figure 35: Ground Floor **Source:** archdaily.com (2022)

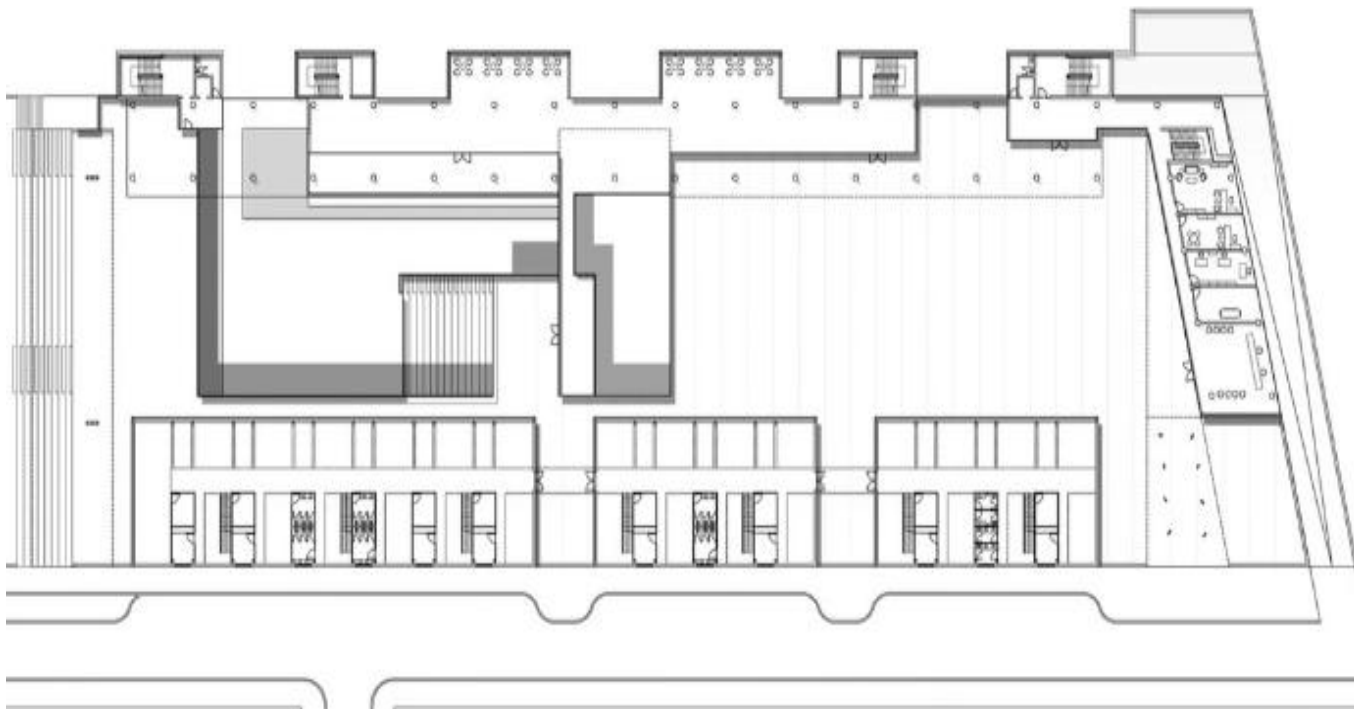


Figure 36: First Floor Plan **Source:** archdaily.com (2022)

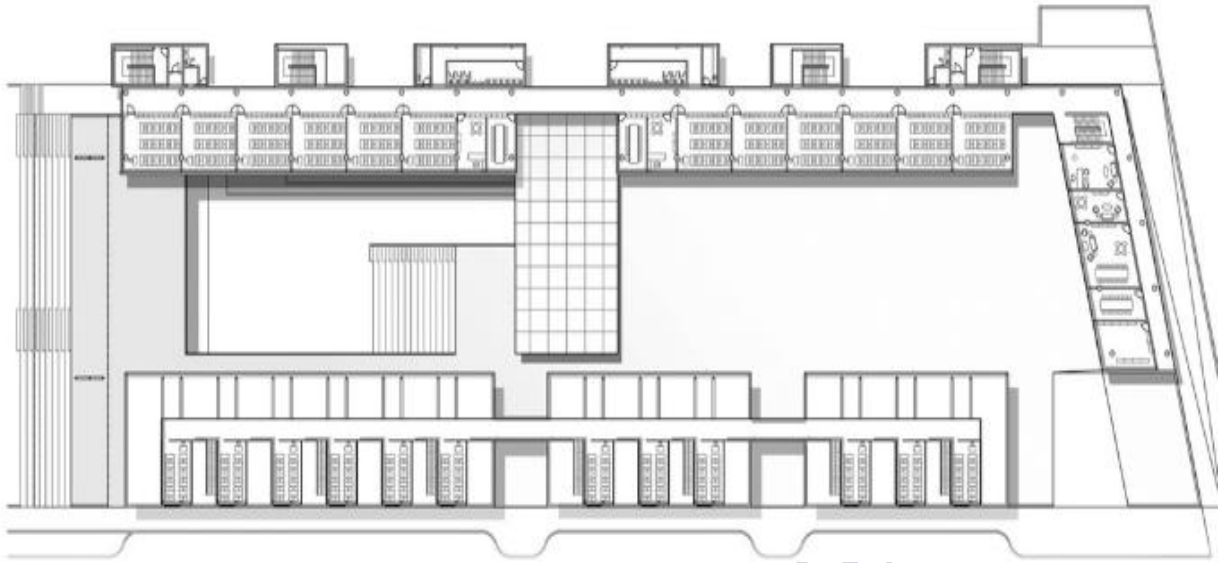


Figure 37: Second Floor Plan. **Source:** archdaily.com (2022)

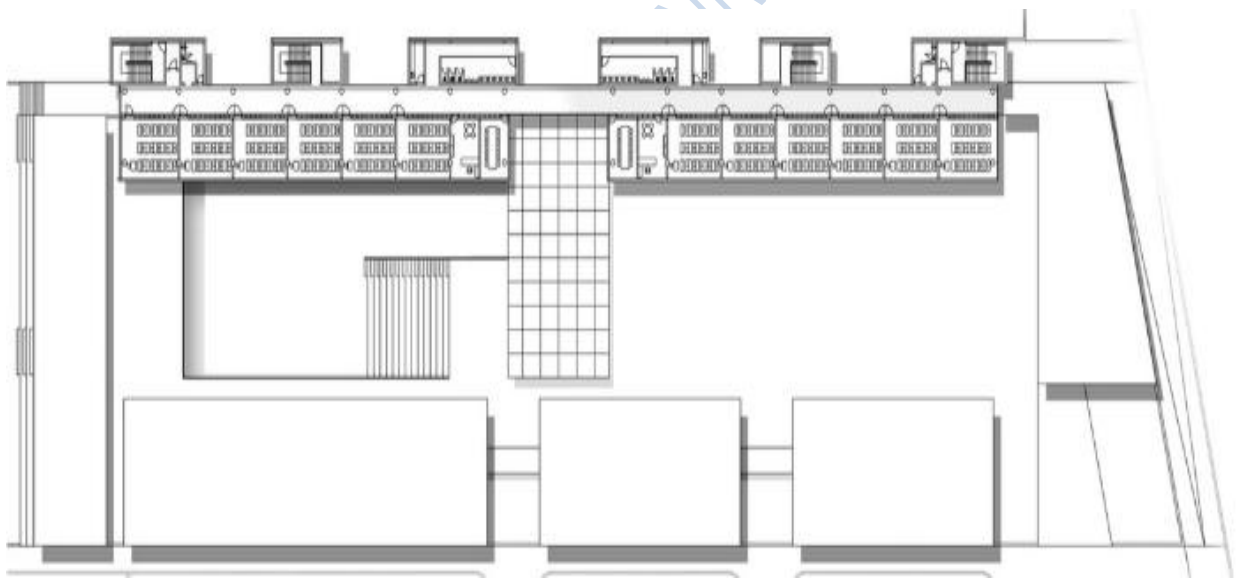


Figure 38: Third Floor Plan **Source:** archdaily.com (2022)

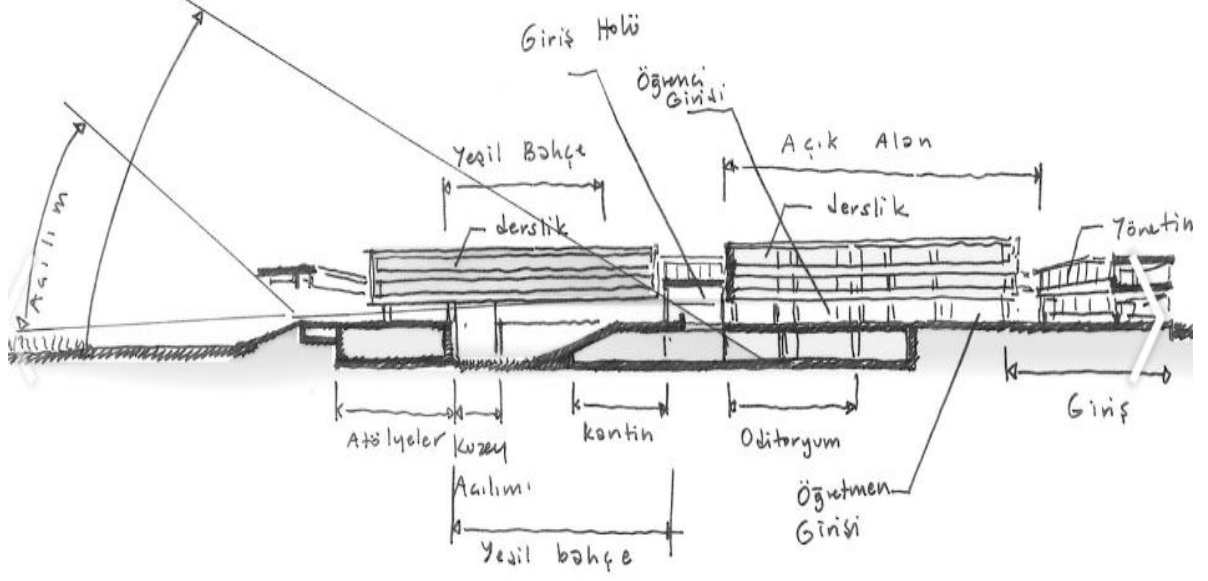


Figure 39: Longitudinal Section. Source: archdaily.com (2022)

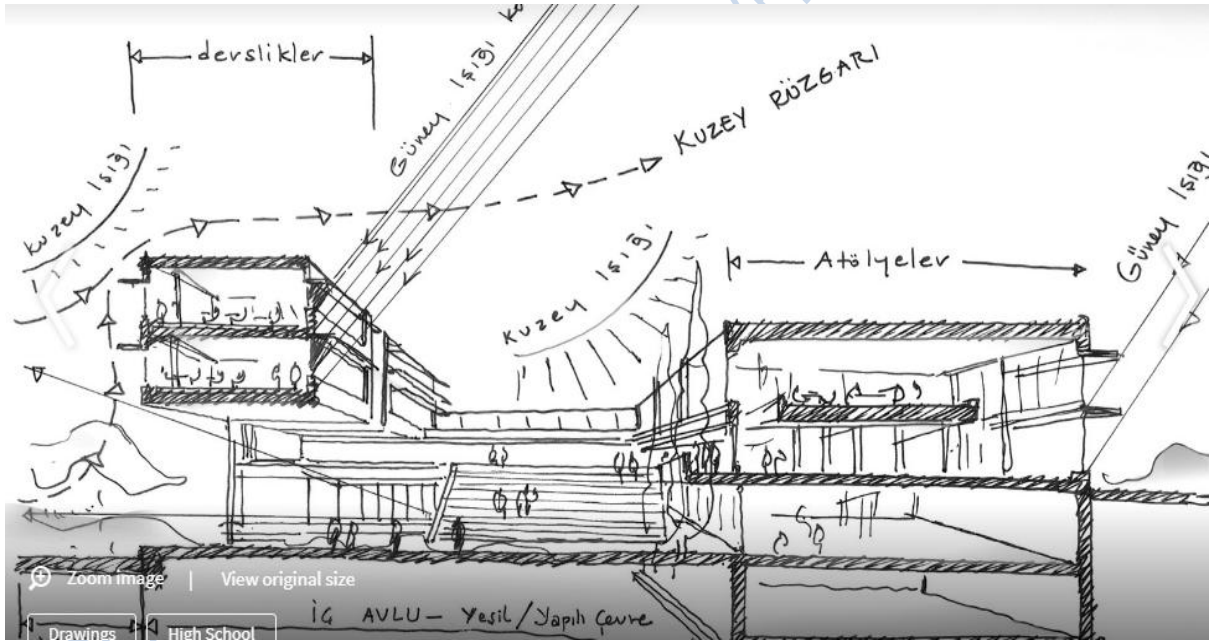


Figure 40: Vertical Section. Source: archdaily.com (2022)



Figure 41: View showing Left side of classroom. **Source:** archdaily.com (2022)



Figure 42: View showing Open space between the classrooms. **Source:** archdaily.com (2022)

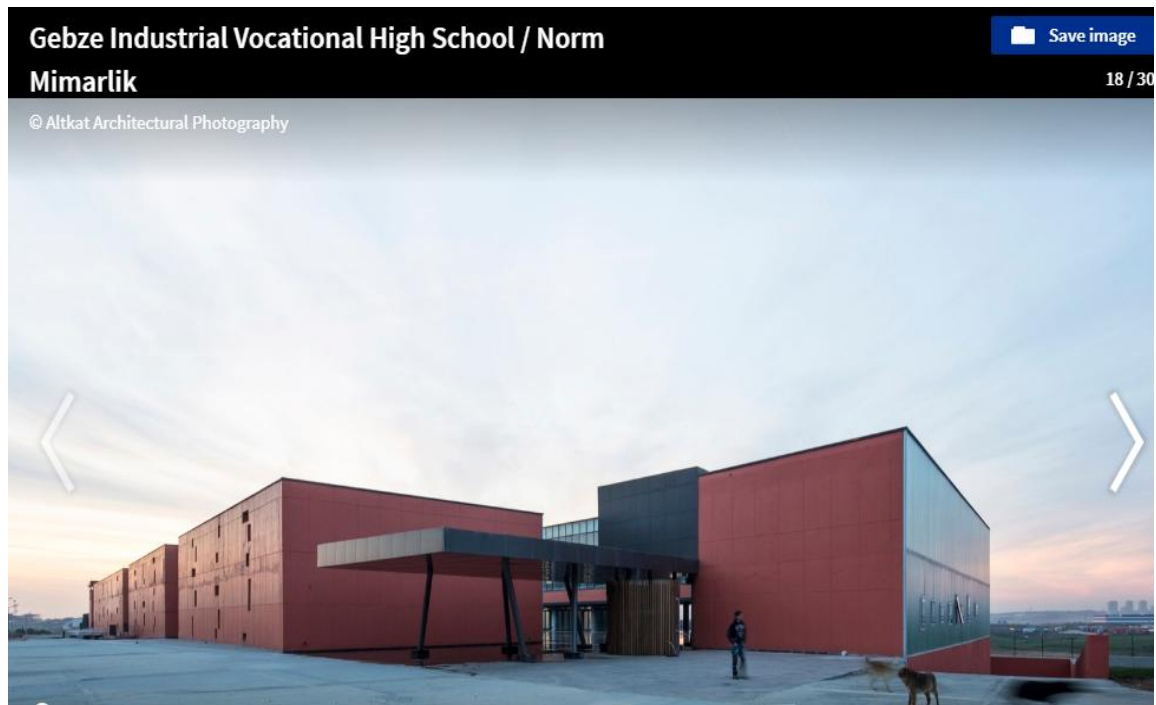


Figure 43: View showing Entrance Approached. **Source:** archdaily.com (2022)



Figure 44: View showing Entrance Approached. **Source:** archdaily.com (2022)



Figure 45: View showing Entrance Left side. **Source:** archdaily.com (2022)

3.3.5. Case Study 5 (Local)

Case Study Five: Vocational Skill & Entrepreneurship Study Center (VSESC)

Location: The Polytechnic Ibadan

Architect: Farcon Consult

Client: The Polytechnic Ibadan

Building Type: Institutional Building

Date Built: 2013

Structural System: Post And Lintel

Climate: Temperate

Architectural Style: Modernist Style

Brief Background

The Center was established in accordance with the Federal Government's initiative through NBTE that all tertiary institutions in Nigeria must establish Entrepreneurship Development Centres (EDC) in order to solve the graduate employment crisis by ensuring that they acquire practical entrepreneurial skills and desirable work habits in addition to their formal education, allowing them to be independent, self-employed, and contributing members of society.

In order to do this, the school administration revived the Vocational Skills and Entrepreneurship Study Center (VSESC) in June 2008 after the demise of the previous Vocational Skills Improvement Unit (VSIU) to act as a nonprofit organisation and source of income. This idea has two components: a program to help graduates of this institution develops their entrepreneurial skills. In actuality, the Vocational Skills and Entrepreneurship Study Center (VSESC) is responsible for ensuring that all Polytechnic, Ibadan graduates are proficient in fashion design.

Skill Department

1. Barbing
2. Beading works
3. Brick/Block moulding and Concreting
4. Catering and Confectioneries
5. Cosmetology
6. Electrical Installation
7. Fisheries,
8. Garment Making
9. GSM Repairs and Servicing
10. Household Production

11. Leather Works
12. Modern Car Repair and Service
13. Pure water Production and Marketing
14. Renewable Energy and Solar Inverter System
15. Textile Technology
16. Transportation and Logistics
17. Website Design and Software development.

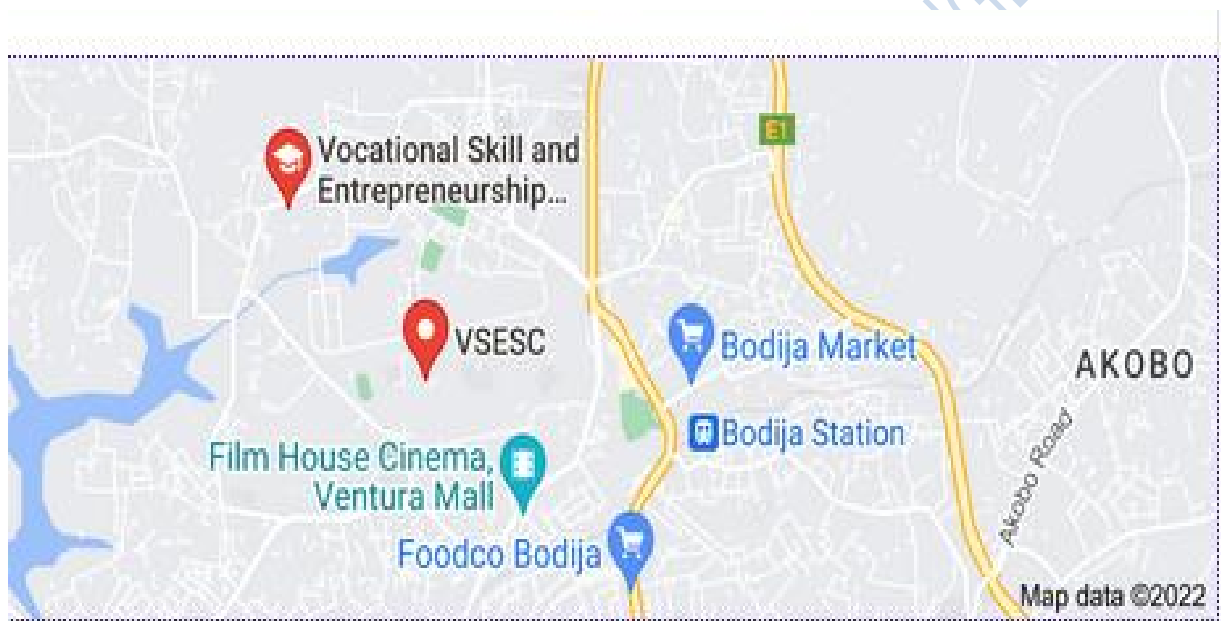


Figure 46: Project Location. Source: [/www.google.com/maps/place/Polytechnic+Ibadan,](http://www.google.com/maps/place/Polytechnic+Ibadan) (2022)



Figure 47: .Source: [/www.google.com/maps/place/Polytechnic+Ibadan,](http://www.google.com/maps/place/Polytechnic+Ibadan) (2022)

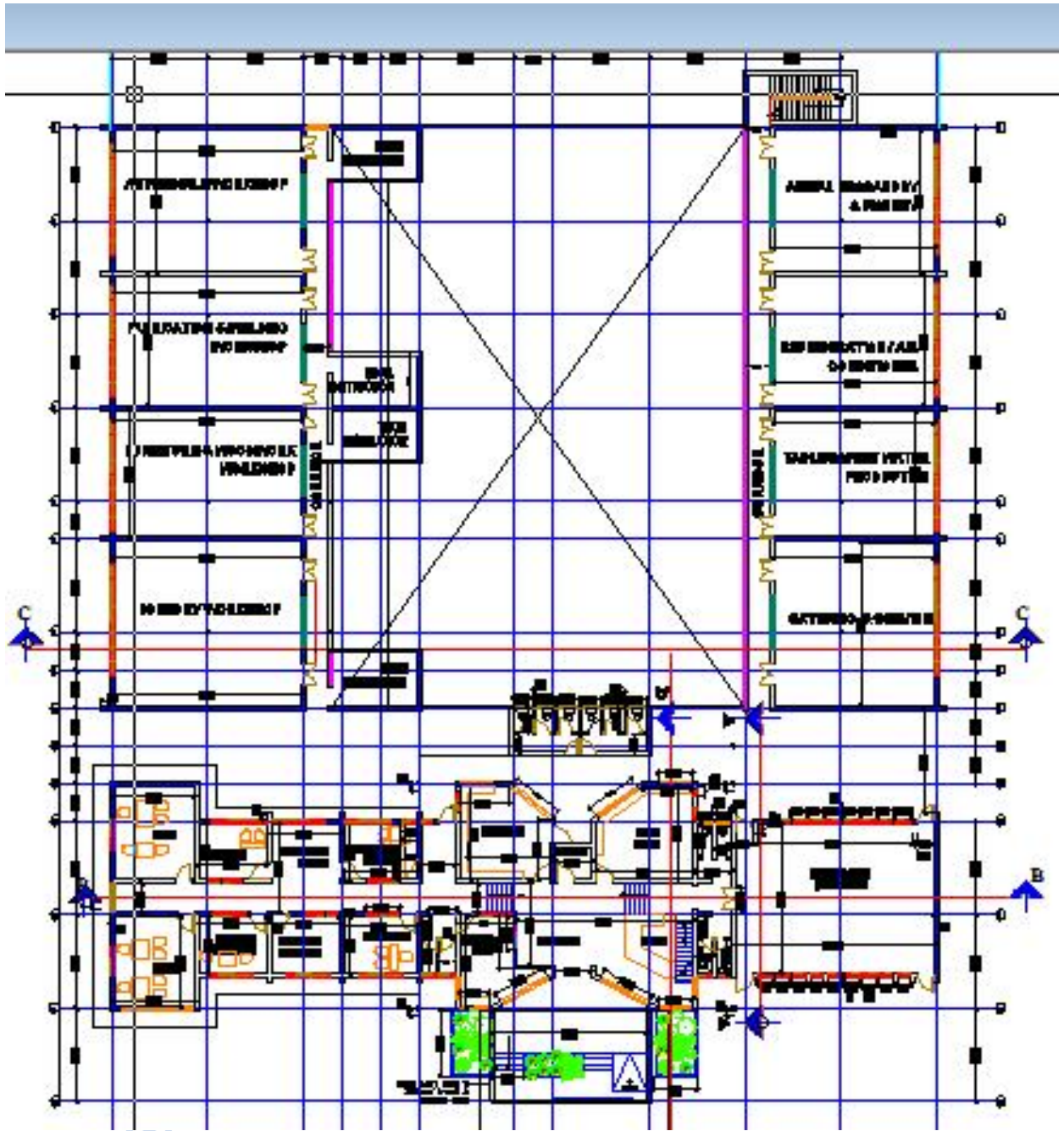


Figure 48: Ground Floor plan. Source: Researcher's fieldwork (2022)

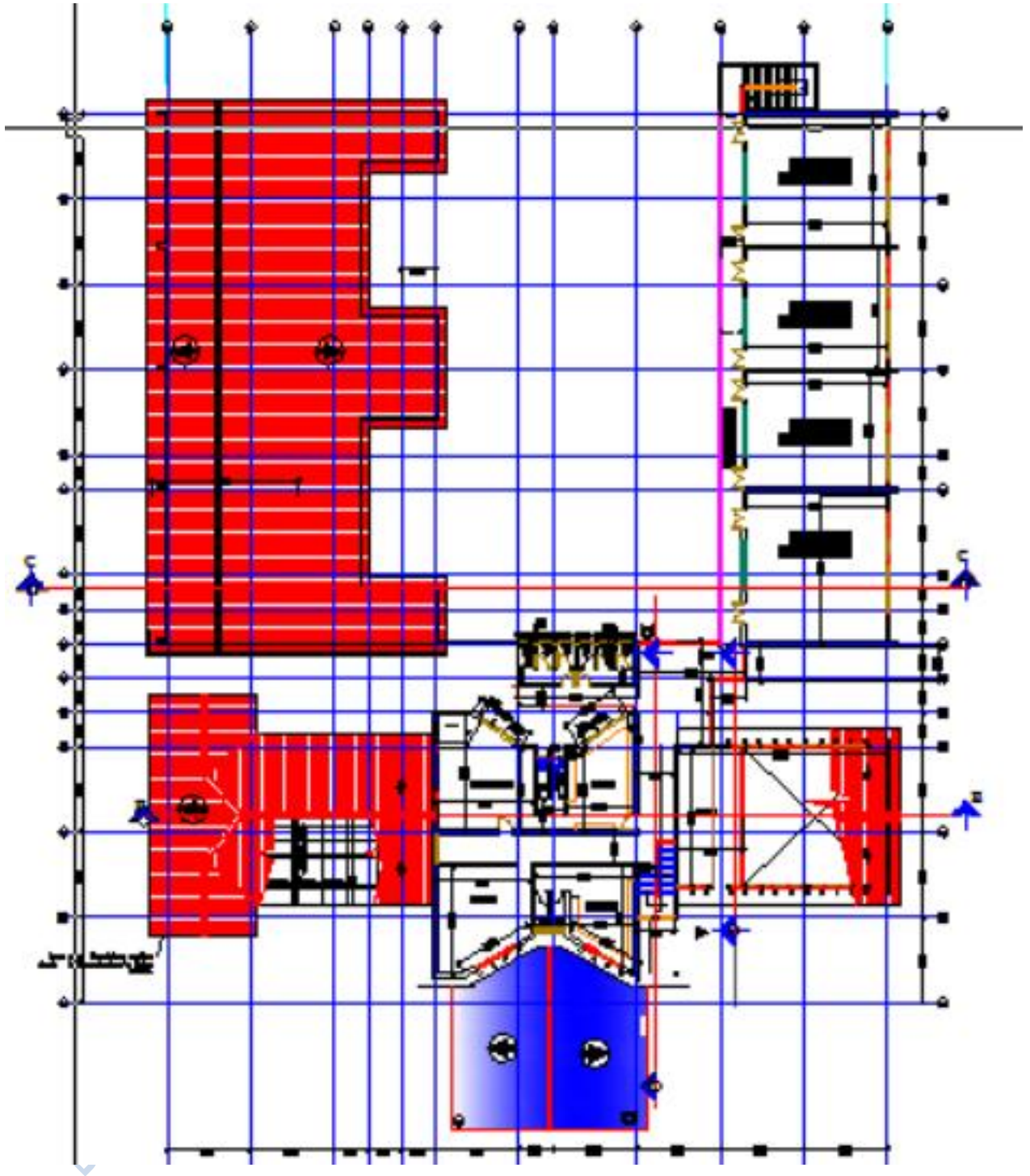


Figure 49: Upper Floor plan. **Source:** Researcher's fieldwork (2022)

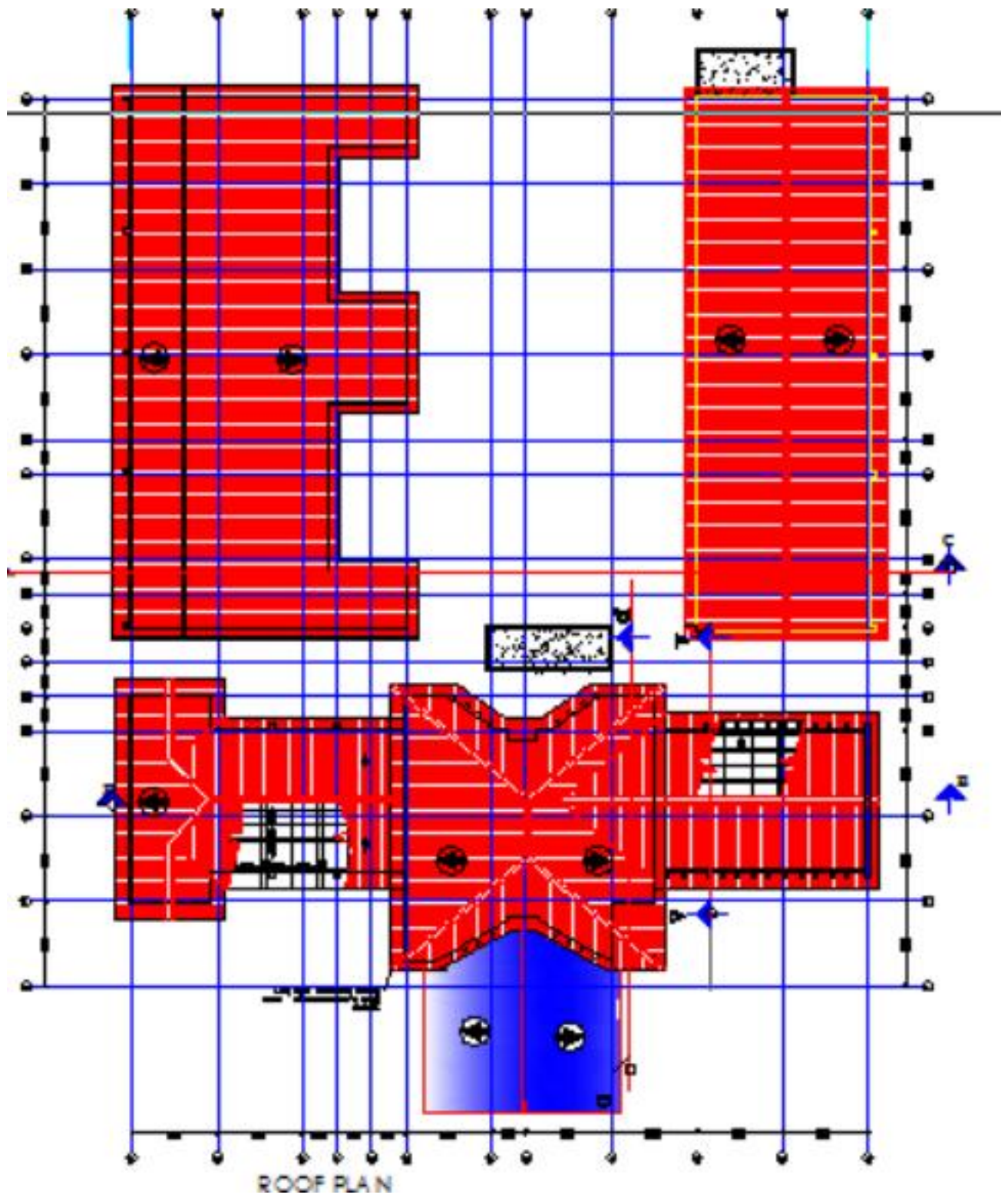


Figure 50: Roof plan. Source: Researcher's fieldwork (2022)

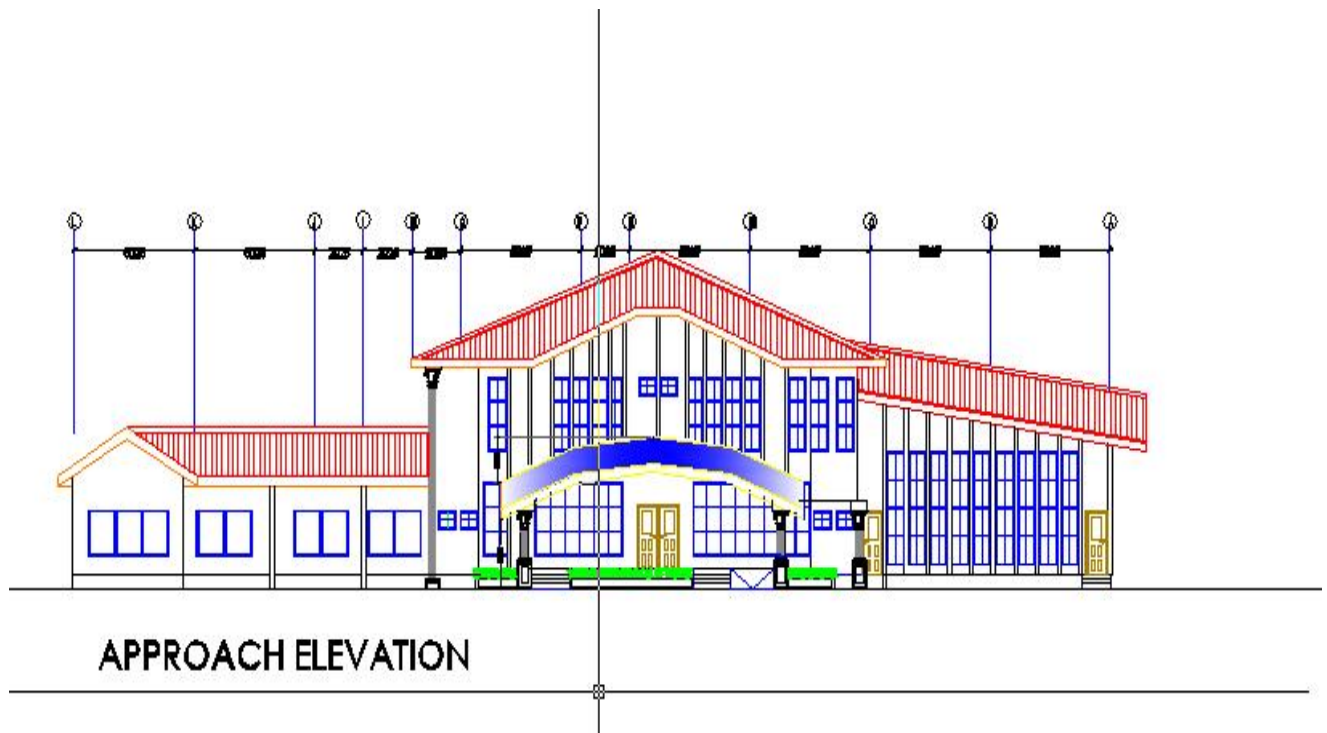


Figure 51: Elevation. Source: Researcher's fieldwork (2022)

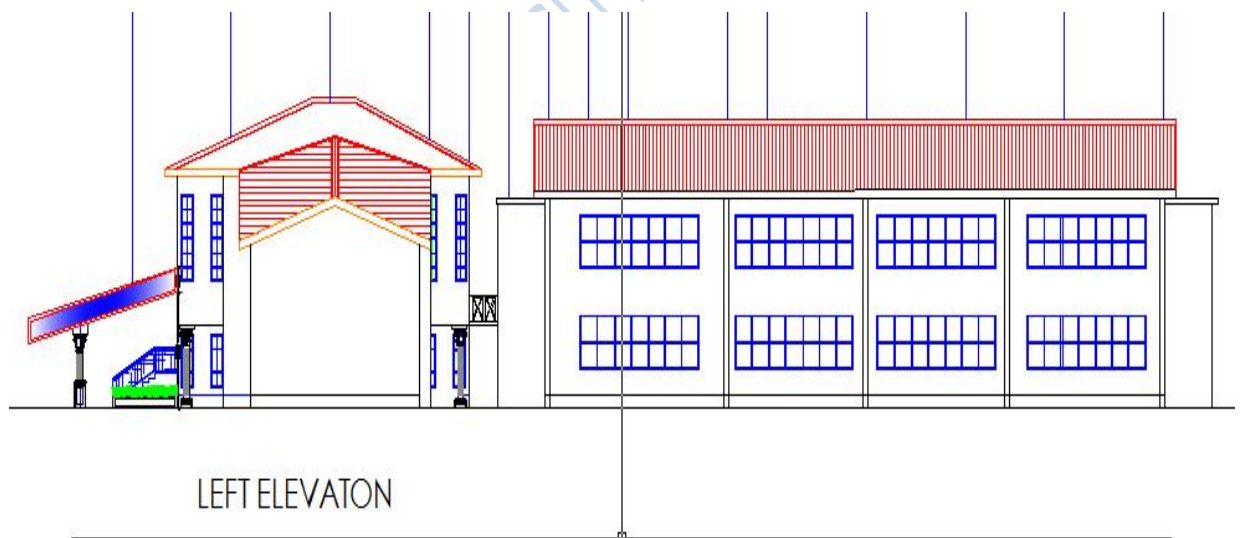


Figure 52: Elevation. Source: Researcher's fieldwork (2022)

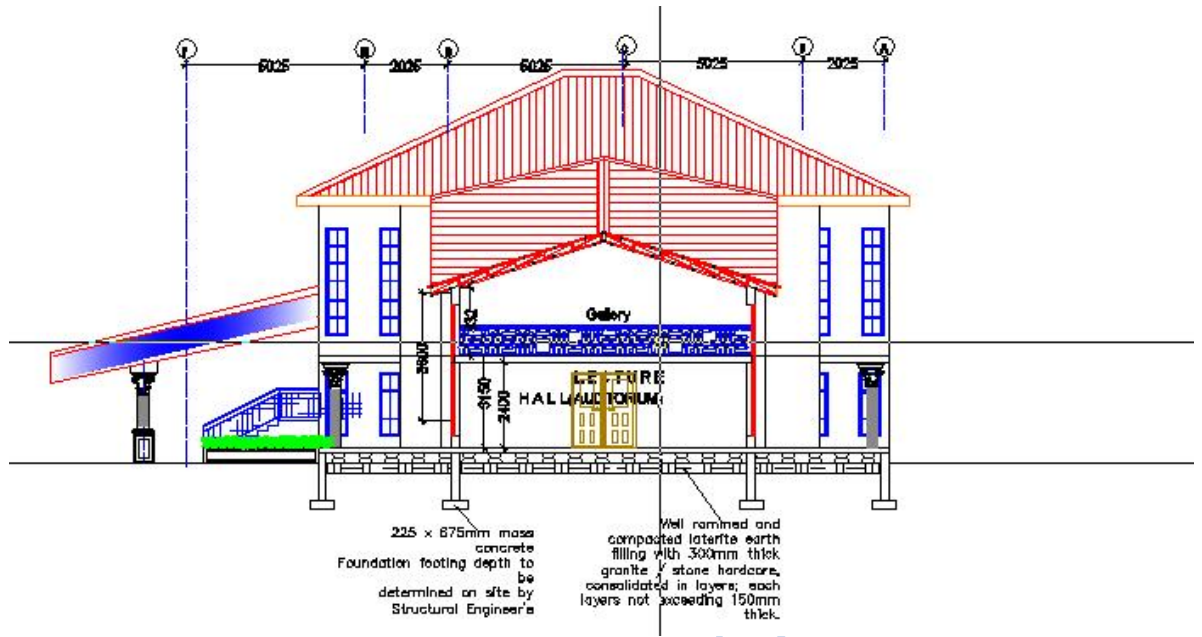


Figure 53: Section. Source: Researcher's fieldwork (2022)

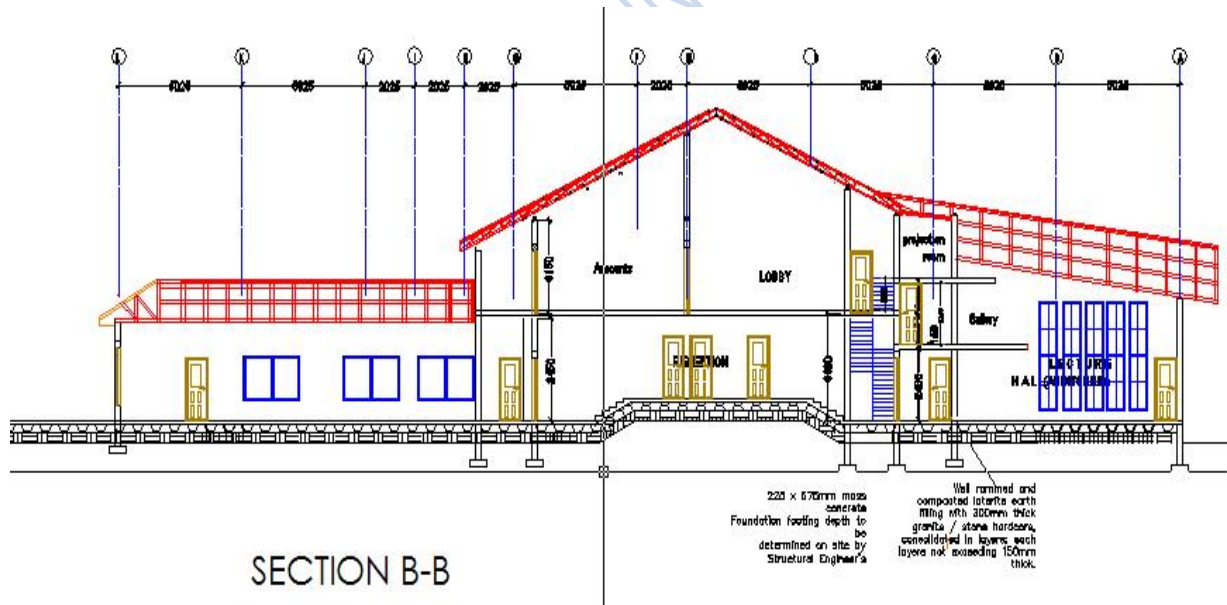


Figure 54: Section. Source: Researcher's fieldwork (2022)



Figure 55: Elevations. **Source:** /www.google.com/maps/place/Polytechnic+Ibadan, (2022)

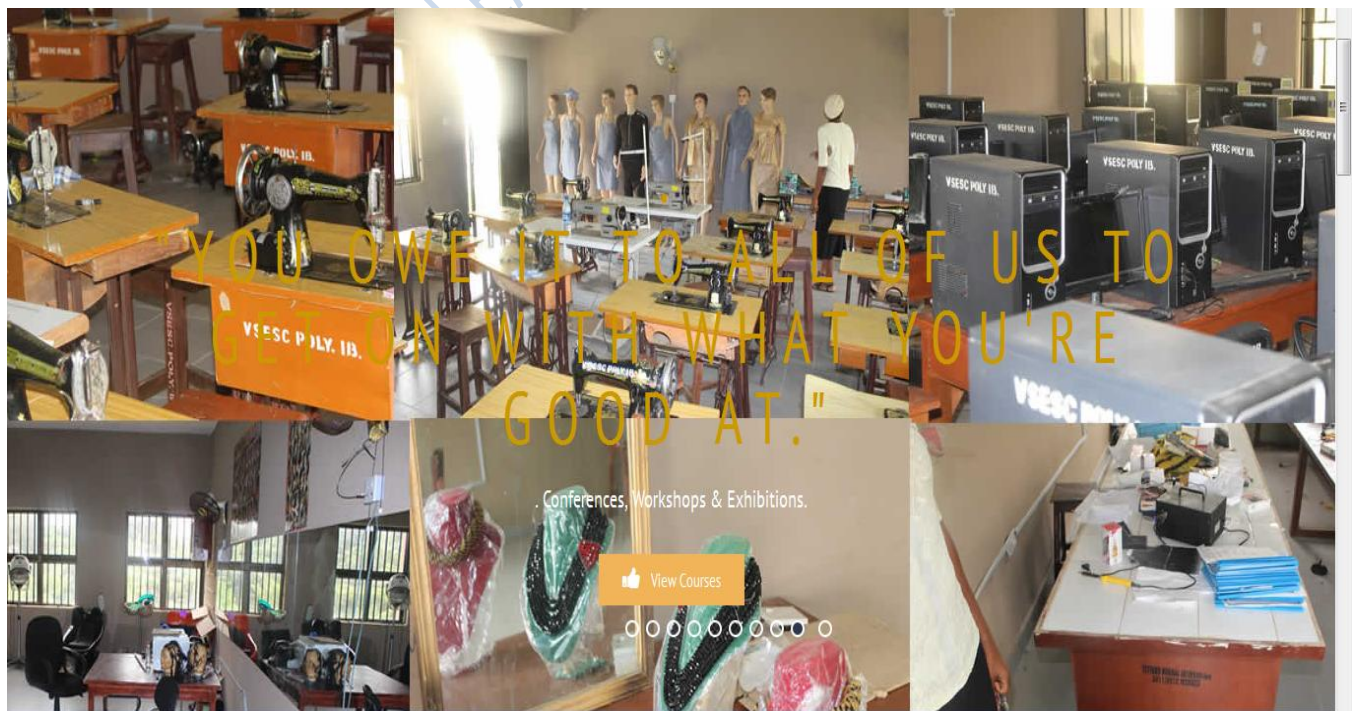


Figure 56: Interior. **Source:** /www.google.com/maps/place/Polytechnic+Ibadan, (2022)

Variables

i. Architectural Style: Both the plan and the elevations used simple geometric forms. The elevations and the plan are constructed by carefully massing these forms. This gives the building a straightforward modernist look.

ii. The facilities' scope includes the main office, vice principal's administrative and academic office, staff office, other offices, classroom blocks, drawing studios, laboratories, workshops, assembly hall, staff quarters, dorm rooms for students, dining hall, and recreation area.

iii. Construction technology: The loadbearing walls structural system, which transfers all loads to the soil through the walls with a hip/gable exposed roof, is used in construction. Bricks and sandcrete blocks rendered with sand mortar make up the walls.

iv. Construction materials: Concrete, sandcrete blocks, bricks, aluminum roofing sheets, glass, steel, and timber roof components are the main materials used to build this facility.

vi. Flexibility: Since load-bearing and partition walls are not fully movable, doing so would compromise the building's structural stability.

Table 8: Case study five summary of findings.

Variable	Adequate (√)	In-Adequate (X)	Not Available (0)
Architectural Form	√		
Scope of Facility	√		
Construction Technology		X	
Building Material	√		
Flexibility and Adaptability			0

3.2.1. Appraisal of the Building

The outcomes from five chosen situations are compared and summarised in the table below. Herningsholm Vocational School and Professional & Technical High School, Mont-De-Marsan were discovered to be the cases with the highest consideration for Flexible and Adaptable Interior Space; as a result, they provide the most suitable Interior or Work Space for adaptability to change in Demand of Space Sizes. The other two, however, don't have an adaptation function.

Table 9: Comparative Analysis of the Cases examined.

Variable	BUSTVTE	HVS	BUTECH	GIVH	VSESC
Architectural Form	√	√	√	√	√
Scope of Facility	√	√	√	√	√
Construction Technology	√	√	√	√	√
Building Material	√	√	√	√	√
Flexibility and Adaptability		√		√	√

Chapter Four

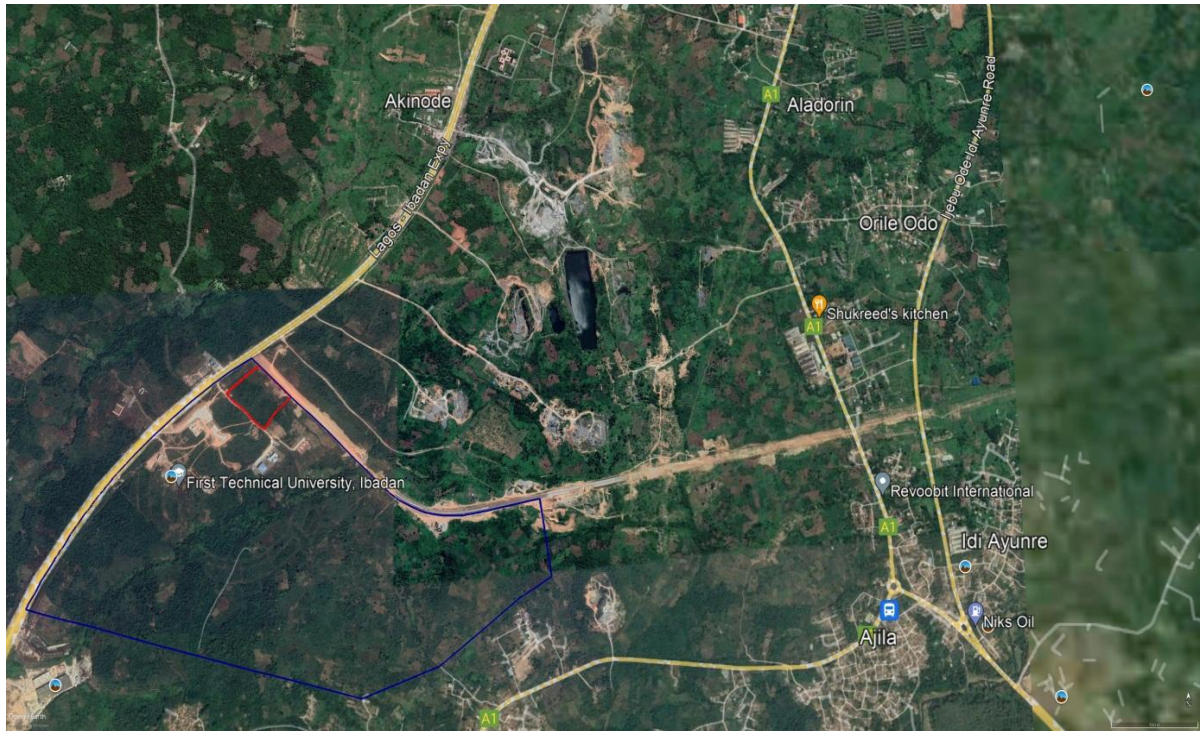
Site Analysis And Design Synthesis

4.1. Study Area

4.1.1. Site Location

The planned project site is situated along a Latitude of 7° 14' 23.8" N and a Longitude of 3° 49' 35.1" E. within the First Technical University (Tech-U) campus in Ibadan, the state capital of Oyo in Nigeria. of 7° 14' 23.8" N and a Longitude of 3° 49' 35.1" E. The University was founded in 2012 by the Oyo State Government to close the skill gap between university graduates' competencies and industry requirements. Tech-U is built on sustainable practices, innovations, and entrepreneurial principles. Learning is conducted through theory, practical, and hands-on experiences. The university campus is located along the Lagos- Ibadan expressway (closer to the Ibadan end). A government-run higher education facility called Tech-U is situated in the city of Ibadan.

Therefore, the University is ideally situated to lead an excellent technical educational system based on innovations and technology to drive growth in Nigeria and Oyo State in particular.



4.1.2. Site Selection Criteria

For this study, two different sites with suitable conditions within the First Technical University (Tech-U) campus were considered. Preliminary site selection criteria used for the location of the proposed Vocational Training Institute facility include the following:

- i. Ease of accessibility,
- ii. Availability of site area and future expansion,
- iii. Visibility,
- iv. Proximity to allied faculties and departments,
- v. Availability of social amenities such as electricity, water, telecommunication network, and good road.

i. Ease of accessibility

Easy accessibility is a very important factor for the institute. The vocational training institute should be easily accessible both vehicularly and for pedestrians without difficulties., the site should be close to a major access road, to achieve this.

ii. Availability of site area and future expansion

Future expansion can either be achieved vertically or horizontally. But to achieve future expansion horizontally, the institution should be situated on a site with a large land mass that will give room for future expansion of the scope or facilities of the vocational training institute.

iii. Visibility

As an institution is a public facility for a vast population of individuals, it is important to situate it in a position where it can be easily seen by everyone to inspire good in-flow of people, and motivate curiosity.

iv. Proximity to urban centers

A vocational training institute should be located in good proximity to urban centers to encourage patronage and sales of manufactured products and hiring of services. The proposal intends to locate the institution in between the two (2) prominent towns of the state so that it can conveniently serve both towns efficiently.

v. Availability of social amenities

The selected site will be worthier consideration if it improves the viability of the proposed project through its nearness to some basic social amenities such as accommodation, health services, telecommunication, electricity, water supply and good motorable roads connected to interurban highways.

4.2.1. Design Criteria

Vocational Training Institute as an educational building design, requires special treatment and attention to the image/aesthetic appearance and flexibility and adaptability of spaces to adapt to varying changes in utility and advancement in teaching technology and

machineries, this is achieved primarily through the functional design of every space by adopting modular design principles and movable partition walls. The issue of form will be considered from both side related point of view and with respect to functional characteristics independent of site, the form organization must be responsive to the learning/teaching process and character of institutional building.

4.2.2. Conceptual Development

The project is a research and experiment to find possible sustainable solutions that would enhance easy scalability of spaces to fit constantly varying functions without necessarily demolishing partition walls and causing waste of resources, time and energy. The one major concept (basic general idea) utilized in the design of this Vocational Training Institute is flexibility and adaptability, which is very vital in institutional designs. This concept can be achieved through the integration of three sub-concept which are; Frame Structure design, Modular Design Principles and Movable Partition walls.

After analyzing several forms and how effective they are in employing flexibility and adaptability in the learning space, rectangular cube has been adopted to be designed as a frame structure so that the partition walls are non-load bearing walls in other to retain integrity in the structural stability of the building while the partitions are movable to scale the spaces are required by a particular function. The proposal would therefore be designed conceptually and architecturally to improve flexibility and adaptability of the interior spaces by incorporating movable non-load bearing partition walls into the design. Nature and technology would also be part of the primary tectonic expression of the building.

The arrangement of the rectangular cube forms is in a manner that shows the cyclic nature of teaching, learning, and innovation.

4.2.3. Building Services

In the allocation of spaces for the various functions present in the Vocational Training Institute, due consideration was given to each space based on the specific activity anticipated for that space. To arrive at the space requirement, maximum space standards were obtained from reference data books. Therefore, the space requirement for this project is shown in the table below:

Table 10 :Space Requirement

Space	Area	Unit
1. Administrative Section		
Director 's Office	72m ²	1
Deputy Director's Office	54m ²	1
Training Director's Office	36m ²	10
Deputy Director's Office	36m ²	12
Accounts/Bursary	72m ²	1
Personnel Unit	36m ²	1
Purchase/Procurement	72m ²	1
Board Room	90m ²	6
General Office	72m ²	16
Exhibition/Gallery	162m ²	16
Display/Sales	486m ²	1
Guidance/Counselling	72m ²	1
Auditorium	486m ²	1

Conveniences	36m ²	12
Entrance/Reception	667m ²	1

2. Academic Section

Instructor's Office

Workshop

Store

Classroom

Studio

Library

3. Accommodation Section

Male Hostel

Female Hostel

Four Bedroom Apartment

Three Bedroom Apartment

Two Bedroom Apartment

One Bedroom Apartment

4. Sports and Recreation

Track and Field

Basketball Court

Volleyball Court

Lawn Tennis Court

5. Ancillary Unit

Sick Bay

Snacks Bar

Shop

Generator

Water Reservoir

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Chapter Five

Conclusion

5.1. Conclusion

The research has attempted to present a purposeful design environment as a positive approach to reduce the rate of unemployment, trafficking and idleness amongst the young minds. The architectural design has focused on organizing various elements, appropriate zoning, effective circulation patterns and achieving flexibility and adaptability within the interior space using movable partitioning system.

Additionally, the overall thesis discovered that using modular design concepts increases the flexibility and adaptability of structures. It also reduces the over waste when the function of a building is changed and easy maintenance by easy replacement of damaged modules. The study also revealed that there is a chance that in the near future, buildings will be used for various changing functions. There should be a unification of concerns between architects and other professionals involve in designs so that flexibility and adaptability qualities are rated high in order of priorities in all designs.

5.2. Recommendations

After carrying out all necessary research on flexibility and adaptability of design of a Vocational Training Institute, the following recommendations are put forward:

- i. Architects and other building professionals should be more enlightened in the aspects of flexibility and adaptability when designing and constructing a Vocational Training Institute and other vocational training facilities. Even though the concept is not new in the International community, it has not been fully embraced within the Nigerian context of architecture. adaptability when designing

and constructing a Vocational Training Institute and other vocational training facilities. Even though the concept is not new in the International community, it has not been fully embraced within the Nigerian context of architecture.

- ii. Vocational Training Institute should be built in the six political zones while already existing ones should be upgraded and maintained to meet with international standards.
- iii. The design of a Vocational Training Institute should adopt the principles of flexibility and adaptability design in order to achieve maximum efficiency of both the building and its users alike, and also to adopt the principles of modular design for speedy construction and easy maintenance of buildings
- iv. iv. Architects should adopt frame structure design principles in the design buildings for improved functionality and easy variation of functions of such building.
- v. Further studies should be done in this area to improve on available resources as adequate and substantial information are not readily available; this may discourage those intending to fully understand and apply these principles on a wider scale.

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Appendix

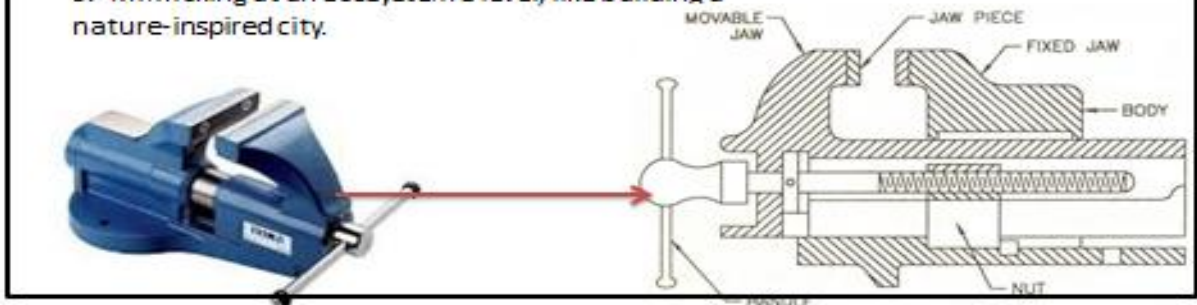
CONCEPTUAL DEVELOPMENT/FRAME WORK

❖ BIOMIMICRY DESIGN OF BENCH VICE

Biomorphism: refers to designs that visually resemble elements from life (they “look like” nature), whereas biomimetic designs focus on function (they “work like” nature). Biomorphic designs can be very beautiful and beneficial, in part because humans have a natural affinity for nature and natural forms.

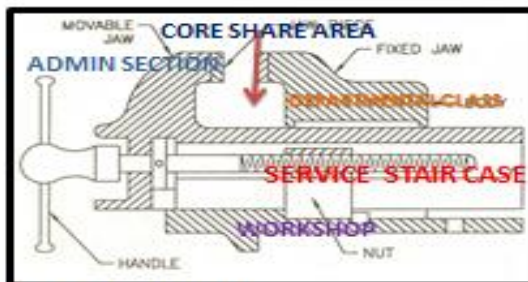
❖ There are three types of biomimicry

1. Copying form and shape.
2. Copying a process, like photosynthesis in a leaf.
3. Mimicking at an ecosystem's level, like building a nature-inspired city.



Appendix 1: Conceptual Development

Concept Bench vice



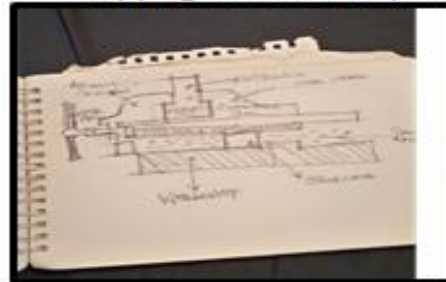
Biomimicry type 3

Mimicking at an ecosystem's level, like building a nature-inspired city.

BENCH VICE ECOSYSTEM: it's a technical tools skilled which is used to hold object. Philosophically “means skilled Bench Vice that holds different skill”

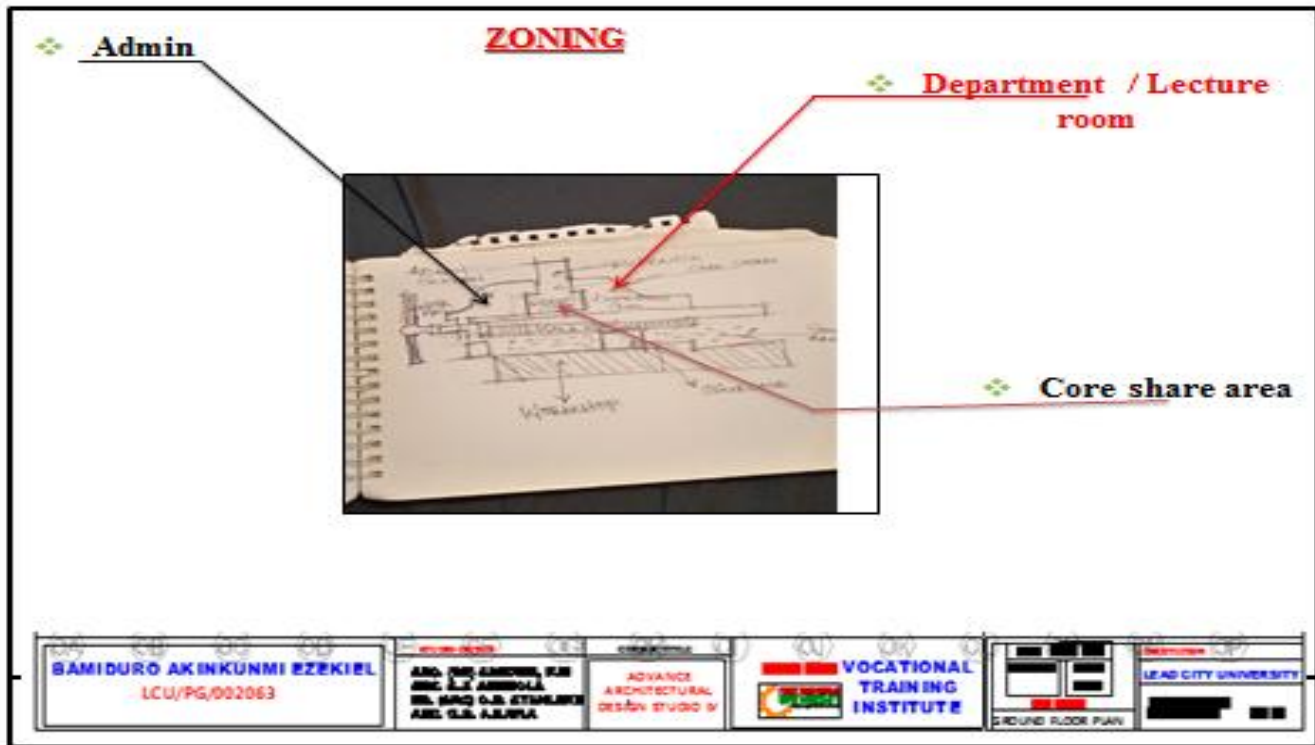
Biomimicry type 1

Copying form and shape.

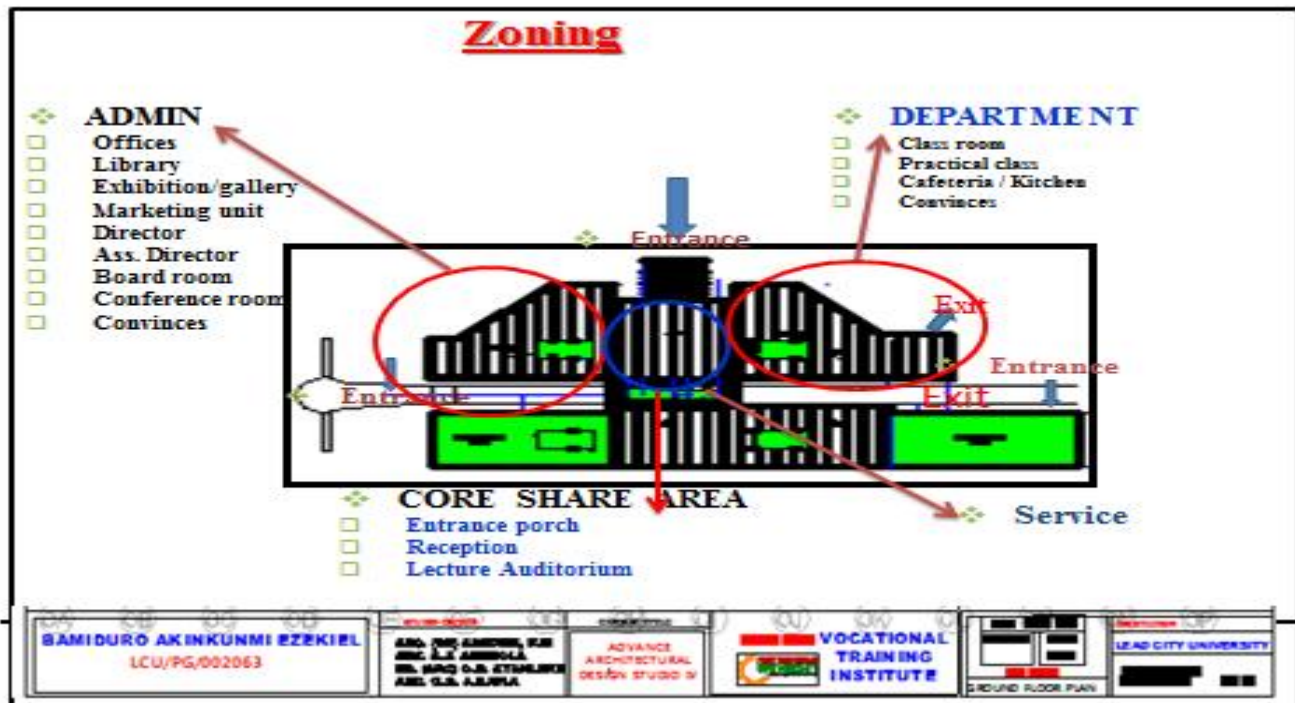


<p>BAMIDURO AKINKUNMI EZEKIEL LCU/PG/002063</p>	<p>AND. PAB. ANTHONY, EUN AND. E.T. AMBOLA MR. MARO O.B. STANLEY AND. G.S. ADEOLA</p>	<p>ADVANCE ARCHITECTURAL DESIGN STUDIO BY</p>	<p>VOCATIONAL TRAINING INSTITUTE</p>	<p>GROUND FLOOR PLAN</p>	<p>LEAD CITY UNIVERSITY</p>
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Appendix 2: Concept



Appendix 3: Zoning



Appendix 4: Zoning

DESIGN CONSIDERATION

Flexibility, Functionality, Services and Aesthetics

❖ Flexibility

Multipurpose, or a space that enables multiple kinds of activities to occur; Repurposable, or transformable to different use cases; Divisible / resizable, as in auditoriums with moveable walls; "Lightly zoned industrial or office space;"



❖ Functionality

In architecture, functionalism (or 'form follows function') is the principle that rather than buildings being designed in accordance with past precedents or stylistic trends (aesthetics), the underlying purpose of the building should determine its form.

Appendix 5: Design Consideration

DESIGN CONSIDERATION

❖ Services

Building services are the systems installed in buildings to make them comfortable, functional, efficient and safe. Building services might include: Building control systems. Energy distribution. Energy supply (gas, electricity and renewable sources such as solar, wind, geothermal and biomass)

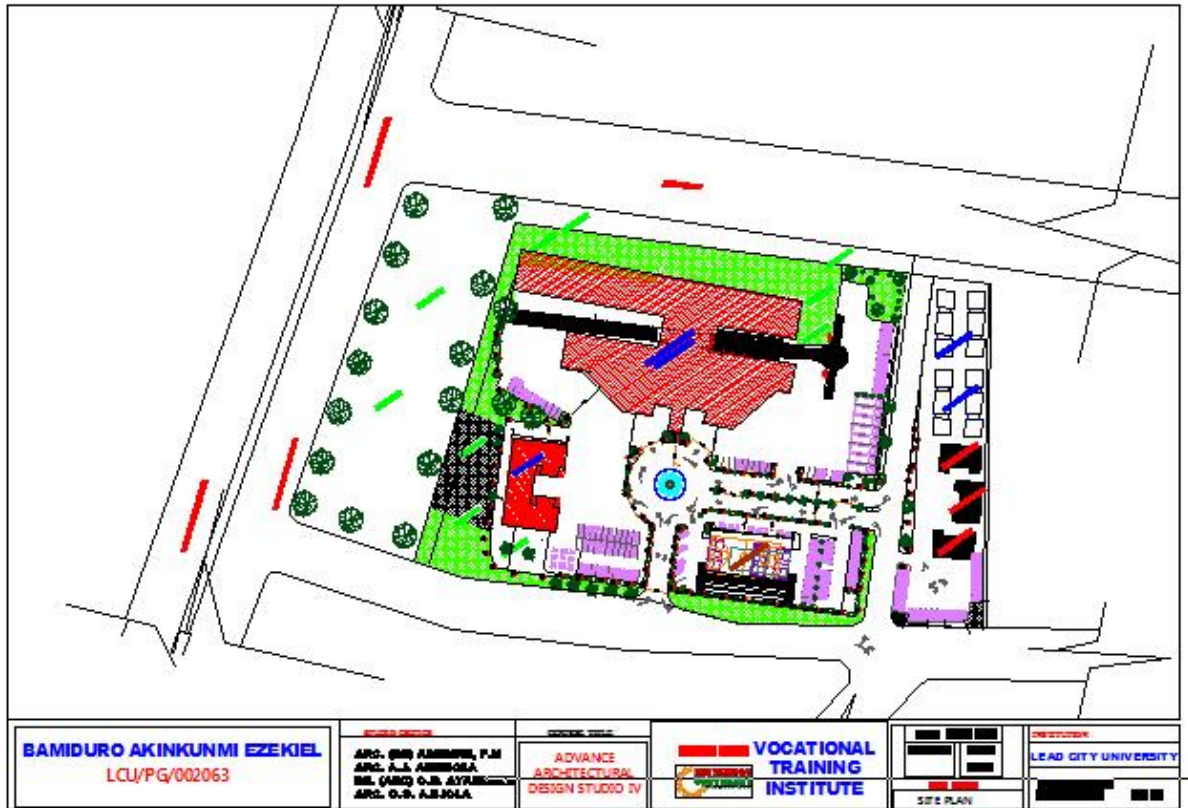


❖ Aesthetic

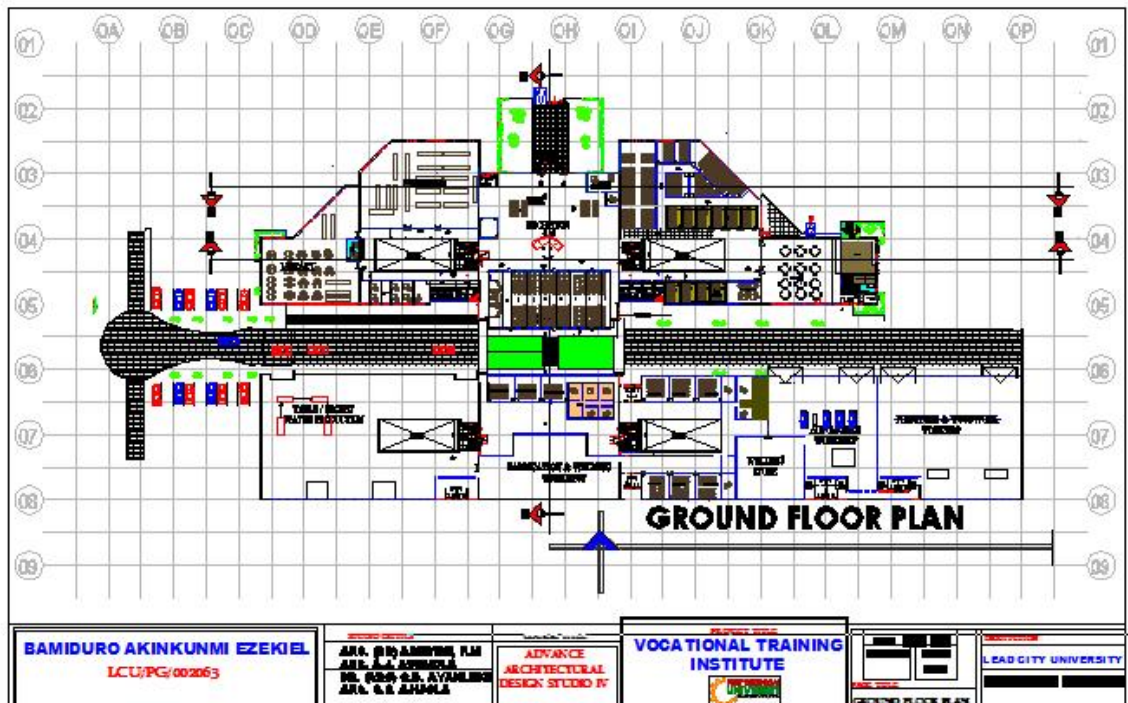
The aesthetics of a building is one of the principal aspects considered in architecture. The appeal of a building covers the combined effects of a building's shape, size, texture, colour, balance, unity, movement, emphasis, contrast, symmetry, proportion, space, alignment, pattern, decoration, culture and context.



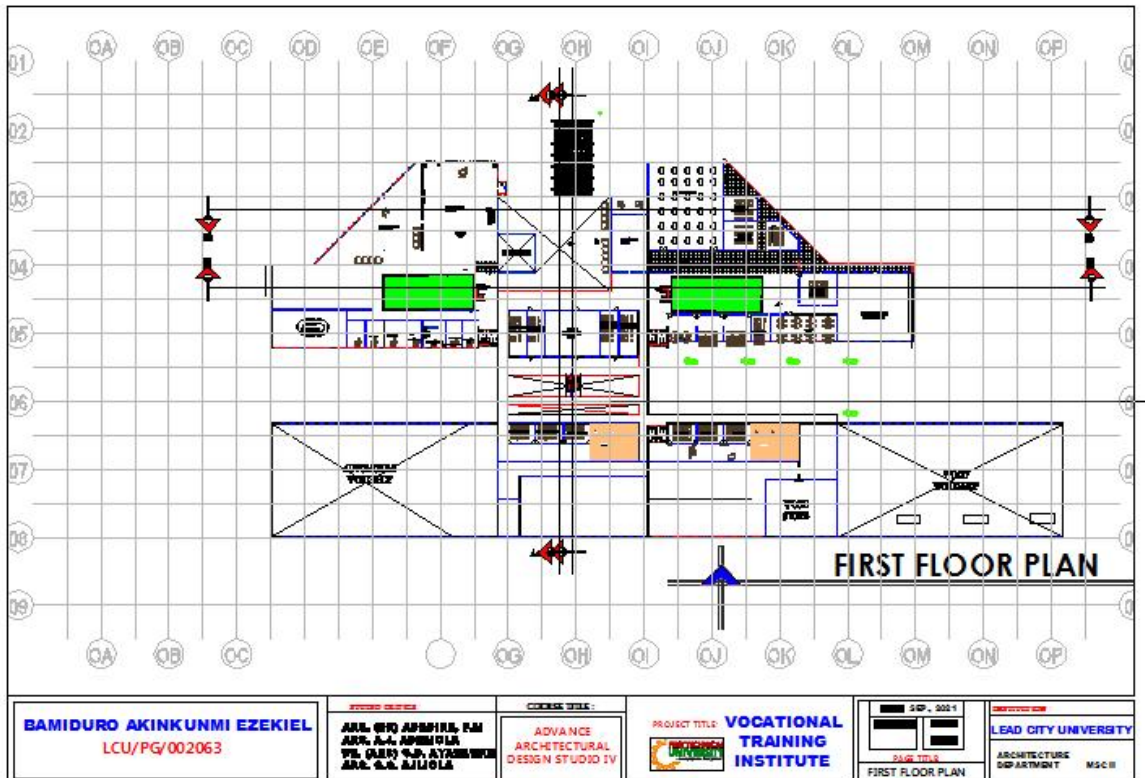
Appendix 6: Design Consideration



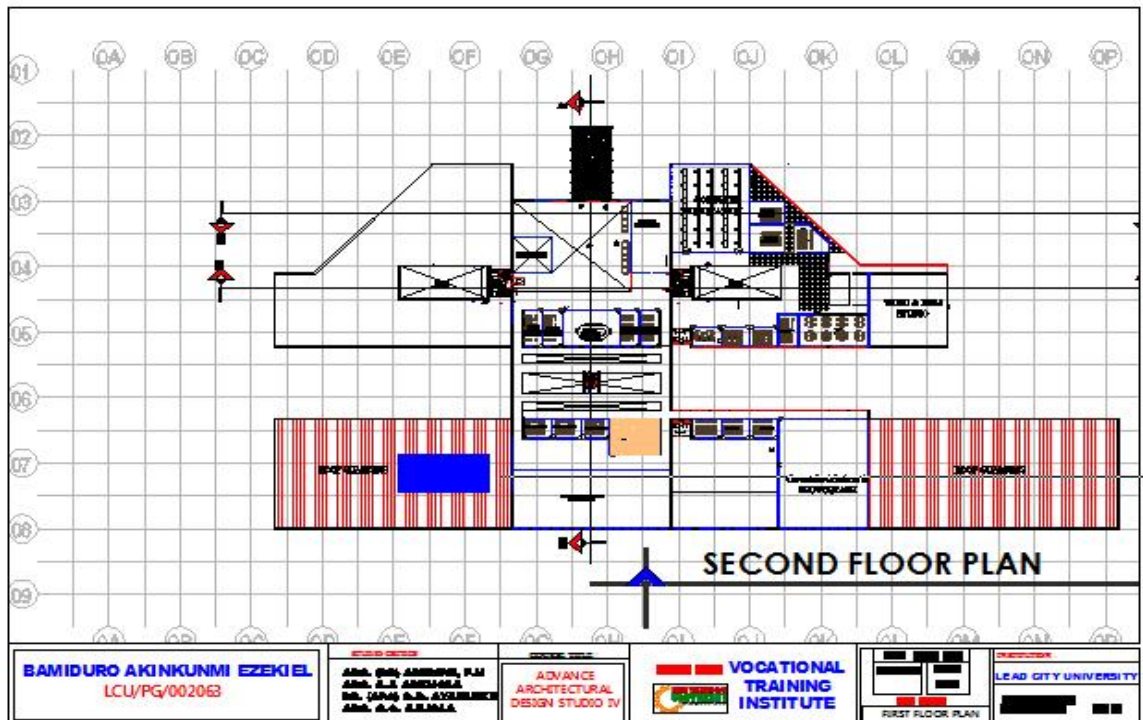
Appendix 7: Site Plan



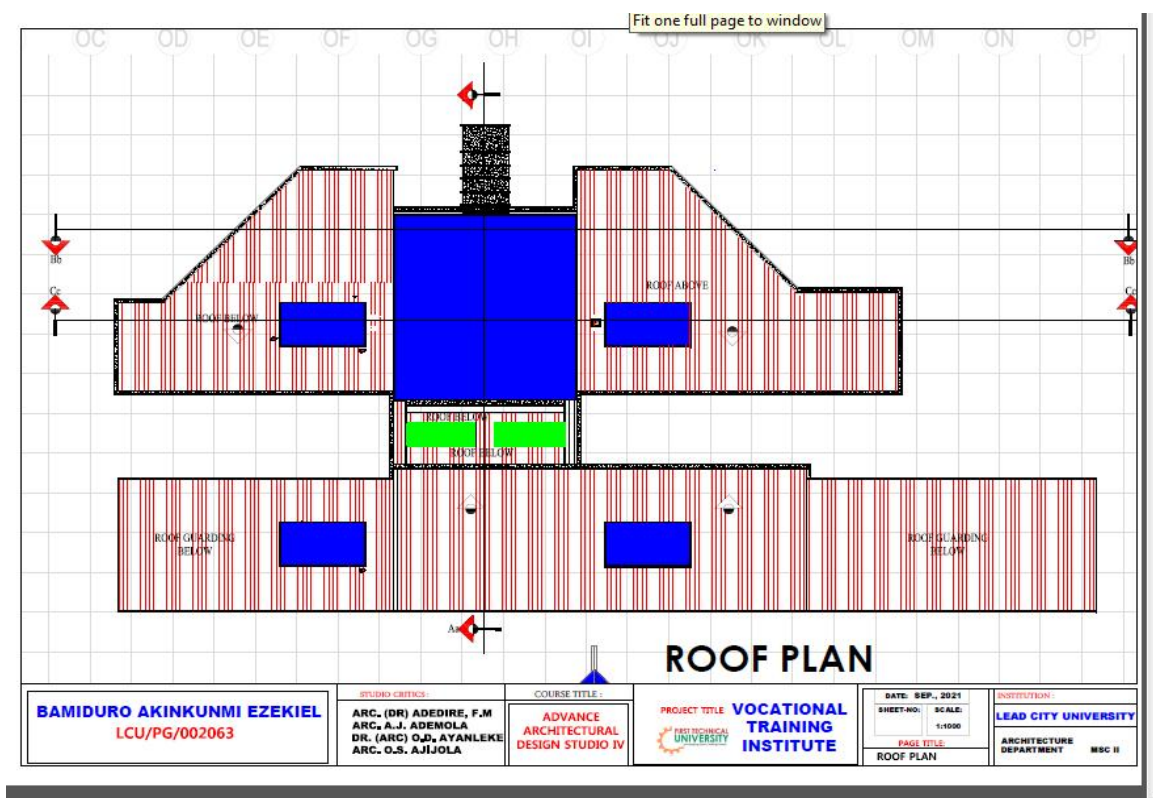
Appendix 8: Ground Floor Plan



Appendix 9: First Floor Plan Concept



Appendix 10: Second Floor Plan Concept



Appendix 11: Roof Plan



Appendix 12: Elevation



Appendix 13: Elevation



Appendix 14: 3d View



Appendix 15: 3d View



Appendix 16: 3d View

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