

## CHAPTER ONE

### INTRODUCTION

#### 1.1 Background of Study

Construction projects, whether monumental skyscrapers or intricate architectural marvels, often rely on scaffolding as a critical component of the construction process (David A. Smith 2005) . Scaffolding provides the necessary support and access for workers to carry out tasks at elevated heights, ensuring safety and efficiency on the job site . In many regions, particularly in Asia, bamboo scaffolding has been a traditional and trusted choice for this purpose due to its strength, flexibility, and sustainability (John A. Ochsendorf (2012)).

However, estimating the costs associated with bamboo scaffolding can be a challenging endeavor. Unlike conventional construction materials, bamboo scaffolding is characterized by its organic nature, which makes predicting expenses a complex task. To address this challenge and streamline the financial aspects of construction projects, there is a growing need for a precise and adaptable estimating equation for determining provisional sums related to bamboo scaffolding.

This study explores the development of an estimating equation tailored specifically to bamboo scaffolding. The equation seeks to factor in critical variables such as scaffolding height, duration of use, type and quantity of bamboo required and labor costs. By doing so, it aims to provide

construction professionals with a reliable tool for budgeting and cost control when bamboo scaffolding is a vital part of their projects.

As we delve deeper into this subject, we will discuss the significance of provisional sums in construction contracts, delve into the unique characteristics of bamboo scaffolding, examine key variables influencing its costs, propose a mathematical model for estimating provisional sums, and explore how this equation can be practically applied in real-world construction scenarios.

This study not only contributes to the effective management of construction budgets but also highlights the continued relevance of bamboo scaffolding as an eco-friendly and cost-effective solution in the ever-evolving world of construction.

## **1.2 Statement of the problem**

In Nigeria, many construction companies handle various projects, from small buildings to large engineering works. They aim to make a profit by carefully planning project costs. However, a significant part of these costs (about 40%) comes from materials (Dada, J. O 2011). Estimating the right quantity of materials for each project part is crucial, but it's not always easy. For items like temporary structures, such as bamboo scaffolds, companies can't accurately calculate the material needed, leading to overspending and

waste (Amaechi, O. O. (2010)).

To tackle this issue, we need a simple formula that quantity surveyors and estimators can easily use. This formula will not only help them make accurate estimates for bamboo scaffolding but also ensure fairness and transparency in the process. By doing so, it will enhance trust and credibility in the construction industry.

This formula will act as a reliable tool for quantity surveyors and estimators in Nigeria. It's designed to be straightforward, making it accessible to all, regardless of their experience. Think of it as a user-friendly calculator, specially designed for estimating the required bamboo scaffolding accurately.

With this formula in hand, quantity surveyors and estimators will no longer need to rely on vague percentage allocations for costs. They can make precise calculations, ensuring they purchase just the right amount of materials. This means no more overspending or wasting resources on excess materials.

But the benefits go beyond cost efficiency. The formula will introduce a new era of transparency and fairness in the estimation process. By providing a clear and data-backed method, it will reduce the potential for fraudulent activities and corruption. This change is essential for building trust and credibility in the construction industry.

### **1.3 Research Questions**

- What are the key construction practices related to bamboo scaffolding?
- What are the estimating constants associated with bamboo scaffolding?
- What is the manhour rate for bamboo scaffolding labor?
- How can basic algebra be applied to create a bamboo scaffolding estimating equation?

#### **1.4 Aim and Objectives of the Study**

The aim of this research is to develop an estimating equation that can be used to determine the provisional lump sum for bamboo scaffolding around building.

- To describe construction technology practices associated with bamboo scaffolding.
- To establish estimating constants associated with bamboo scaffolding.
- To establish manhour rate for bamboo scaffolding .
- To deploy basic algebra to model the insights obtained from 1, 2, 3 above into bamboo scaffolding estimating equation.

#### **1.5 Significance of the Study**

This study which will help to ascertain the quantities of materials required

for construction of independent bamboo scaffold around building, shall at the end be useful to the following:

- Quantity surveyor -it will help the quantity surveyor to carry out an adequate cost planning.
- Contractor-it will help contractors to know the quantity of materials needed for constructing independent bamboo scaffold.
- Client -it enables the client to know his financial commitment as regards to independent bamboo scaffold.

### **1.6 Scope and Delimitation**

The subject of this study is specially for generating the cost estimating model for independent Scaffold in building construction; for building with rectangular and square shape, and the use of bamboo scaffolding in building of maximum of Two suspended slab/ Duplex in Anambra state.

### **1.7 Definition of special terms**

**Equation** –An equation is a mathematical statement that asserts the equality of two expressions.

**Develop**– create, build, or expand something

**Estimate** - this is a probable

**Cost Estimate** - this is a probable amount that could be paid for a material or service

**Provisional Sum-** Provisional sums are employed when there is uncertainty about the scope, nature, or extent of certain work or materials needed for the project.

**Scaffold** - a temporal structure that provides support for construction worker to work at heights beyond their reach.

**Scaffolding**-this is the process of constructing scaffold

**Scaffolder**-this is an expert in constructing scaffolds.

**Scaffold contractors** -this is a person who solicits for a scaffolding contracts

**Bamboo**-is a woody perennial plant that is use in constructing scaffold

**Bamboo Scaffold**-this is a scaffold made of bamboos.

## **CHAPTER TWO**

### **REVIEW OF RELATED LITERATURE**

#### **2.0 INTRODUCTION**

Despite its importance, cost estimation for preliminary construction works has received limited scholarly attention. This chapter delves into scaffolding construction techniques, estimating constants, bamboo scaffolding, manhour rates, and empirical research on cost estimation by esteemed construction industry experts.

#### **2.1 SCAFFOLDING CONSTRUCTION TECHNOLOGY**

Scaffolding, within the realm of construction technology, is a fundamental and indispensable framework designed to provide temporary support, access, and a safe working platform for construction workers and contractors during the construction, maintenance, repair, or renovation of buildings, bridges, and various other structures (R. Chudley and Roger Greeno 2020). This technology can be likened to the vital scaffolding used in the theater to support and enhance a performance, but in the construction context, it plays a crucial role in facilitating the actual construction process (John O'Connor and Chris March 2015).

### **2.1.1 Key Features and Functions:**

Scaffolding is characterized by several key features and functions:

**Support and Safety:** According to ( David Ball and David Walters 2017 )

One of the primary functions of scaffolding is to offer a stable and secure support structure for workers, tools, and materials. It is engineered to withstand various loads and provide a level, safe working surface, allowing workers to perform their tasks with confidence and reduced risk of accidents (Eduardo J. Torroja 2010).

**Accessibility:** According to (Occupational Safety and Health Administration (OSHA) 2021) Scaffolding is designed to grant access to elevated areas of a construction site that might otherwise be challenging or dangerous to reach. It enhances the mobility of workers, enabling them to work at various heights and locations within the construction project ( John Templer 2011 ).

**Versatility:** Scaffolding is versatile and adaptable to a wide range of construction scenarios (Michael R. Lindeburg 2021 ) . It can be customized

to suit the specific needs of different projects, whether they involve building a skyscraper, repairing a historical monument, or constructing a simple house (National Access and Scaffolding Confederation (NASC) 2020 ).

**Temporary Nature:** Scaffolding is temporary in nature, meaning it is erected at the commencement of a construction project and dismantled upon its completion (John Templer 2021 ). This temporary aspect aligns with its primary purpose of facilitating construction activities, and it does not become a permanent part of the finished structure (National Access and Scaffolding Confederation (NASC) 2020 ). .

### **2.1.2 Components of Scaffolding:**

Scaffolding structures are composed of various essential components, each with its specific role and function:

**Standards (Uprights):** These are vertical tubes or posts that form the main framework of the scaffolding. They provide the vertical support for the entire structure.

**Ledgers (Horizontal Tubes):** Ledgers are horizontal tubes that connect the standards, providing stability and supporting the platform or working surface.

**Transoms:** These are placed horizontally and connect the ledgers, further enhancing the stability of the scaffolding.

**Braces:** Braces are diagonal or cross-bracing elements that help distribute loads and provide lateral support, preventing the scaffold from swaying.

**Platforms:** Platforms or decks are the working surfaces where construction tasks are executed. They can be made from wood, steel, or other materials and can vary in size and configuration.

**Guardrails:** Guardrails are essential for worker safety, preventing accidental falls from elevated platforms.

### **2.1.3 Types of Scaffolding:**

According to (Occupational Safety and Health Administration (OSHA) 2021) Scaffolding technology has evolved over time, leading to various types of scaffolding to meet specific project requirements. These types include frame scaffolding, tube and coupler scaffolding, system scaffolding, and mobile scaffolding, among others. Each type is chosen based on factors such as project design, accessibility needs, and the materials being used.

#### **Frame Scaffolding:**

**Use:** Frame scaffolding, also known as tubular scaffolding, is one of the most common and versatile scaffolding types. It is used for a wide range of projects, from residential buildings to commercial structures. Frame scaffolding is highly adaptable, making it suitable for both exterior and interior work (C. Schumacher and R. Yahr 2019) .

**Features:** This type of scaffolding consists of vertical and horizontal frames interconnected with cross braces. It is easy to assemble, dismantle, and reconfigure, making it an ideal choice for projects with changing requirements.

#### **Tube and Coupler Scaffolding:**

**Use:** Tube and coupler scaffolding, characterized by the use of tubes and couplers for assembly, is employed in various projects, including industrial and large-scale construction. Its flexibility and load-bearing capacity make

it suitable for heavy-duty tasks (C. Schumacher e tal 2019) .

**Features:** This scaffolding type utilizes steel or aluminum tubes and couplers for a secure and adaptable structure. Its modularity allows for customization to accommodate different project designs and complexities.

### **System Scaffolding:**

**Use:** System scaffolding, also referred to as modular scaffolding, is a versatile choice used in both small and large-scale projects. It is particularly beneficial for projects with complex geometries, such as curved facades or irregularly shaped structures.

**Features:** System scaffolding employs pre-engineered components that fit together, providing stability and safety. It is easily adjustable, and components are designed to interlock, simplifying the assembly process.

### **Mobile Scaffolding:**

**Use:** Mobile scaffolding, often equipped with wheels, is employed in projects requiring frequent repositioning, such as painting, maintenance, and light construction. It provides an elevated and movable work platform.

**Features:** This type of scaffolding is designed for easy mobility and can be quickly moved to different work areas. It offers a convenient and safe solution for projects that require workers to access multiple locations.

### **Cantilever Scaffolding:**

**Use:** Cantilever scaffolding is utilized when access is needed in areas where ground support is limited or obstructed, such as building ledges or overhanging structures.

**Features:** It consists of horizontal beams or platforms supported at one end, anchored to the building's structure. This design allows for access to challenging areas while maintaining stability and safety.

### **Suspended Scaffolding:**

**Use:** Suspended scaffolding is often utilized for tasks like window cleaning, painting, and maintenance of tall structures. It is ideal for situations where a scaffold cannot be supported from the ground.

**Features:** Suspended scaffolding involves platforms suspended by ropes or cables from an overhead support structure. Workers can be lowered or raised to the required height, making it a practical choice for high-rise projects.

### **Hanging Bracket Scaffolding:**

**Use:** Hanging bracket scaffolding is employed for external wall construction and renovation projects where external supports are essential.

**Features:** This type of scaffolding is attached to the building's facade, offering a secure platform for workers. It is particularly useful for tasks like bricklaying and plastering.

### **Patented Scaffolding:**

**Use:** Patented scaffolding is a specialized system often used for specific projects or maintenance tasks. It is pre-engineered and highly efficient, making it a valuable choice for rapid deployment.

**Features:** Patented scaffolding typically comes in prefabricated components that are quick to assemble. It is commonly used for short-duration projects

and is known for its ease of use.

## **2.2 Importance of Scaffold Safety:**

Safety is of paramount importance in scaffolding technology (C. Schumacher et al 2019). Accidents related to scaffolding can lead to severe injuries or even fatalities. Therefore, adherence to safety standards and guidelines, proper training for workers, and regular inspections are essential to ensure a secure working environment (David G. Ballheimer 2020).

In summary, scaffolding construction technology is a multifaceted system of temporary structures designed to facilitate construction work by providing access, support, and safety for workers at elevated heights. It is an indispensable tool in the construction industry, tailored to specific project requirements, and guided by safety protocols to ensure that construction activities are conducted efficiently and securely.

## **2.3 ESTIMATING CONSTANTS**

Estimating constants are numerical values that represent specific factors influencing the cost or quantity of a particular item or process (Paul S. Chinowsky 2020). These constants are typically derived from historical data, industry standards, or empirical relationships and are used to develop estimating equations or formulas for accurate cost or quantity predictions (Brian Atkin and Adrian Brooks 2018).

In the context of bamboo scaffolding, estimating constants are essential for

determining the accurate number of bamboo poles required for a building project. These constants account for various aspects of the scaffolding structure, material costs, and labor requirements (Alaa S. Abd-El-Aziz 2019).

Here's a comprehensive and easy-to-understand list of estimating constants you'll need:

1. Length
2. width
3. Distance away from the building
4. Height of the building
5. Foundation depth of the scaffold
6. Centre to centre spacing ( horizontal )
7. Centre to centre spacing ( vertical )
8. Joint of the scaffold
9. Standard length of a bamboo used
10. Laps of the bamboo
11. Length of binding wire per joint
13. Number of Nails at a joint
14. Number of Nails at a lap

1. **Length:** The length of the scaffolding structure, measured in meters. It represents the horizontal extent of the scaffolding along the building façade or the area requiring access.

2. **Width:** The width of the scaffolding structure, measured in meters. It represents the perpendicular dimension to the length, indicating the depth of the scaffolding from the building.
3. **Distance away from the building:** The distance between the scaffolding structure and the building, measured in meters. It ensures a safe working space between the scaffolding and the building while providing adequate access for construction activities.
4. **Height of the building:** The height of the building or structure that the scaffolding is intended to reach, measured in meters. It determines the vertical extent of the scaffolding and the number of levels required.
5. **Foundation depth of the scaffold:** The depth of the foundation holes for the scaffolding poles, measured in meters. It ensures the stability and load-bearing capacity of the scaffolding structure.
6. **Center to center spacing (horizontal):** The horizontal distance between the centers of adjacent scaffolding poles, measured in meters. It determines the density of the scaffolding structure and the load distribution.
7. **Center to center spacing (vertical):** The vertical distance between the centers of scaffolding poles on different levels, measured in meters. It dictates the spacing between working platforms and the overall height of each level.
8. **Joint of the scaffold:** The type of connection used to join bamboo poles in the scaffolding structure, such as lashings, couplers, or bamboo nails. It affects the stability and load transfer between poles.
9. **Standard length of a bamboo used:** The typical length of a bamboo pole used for scaffolding, measured in meters. It determines the number of poles required for vertical and horizontal members.

10. **Laps of the bamboo:** The number of overlapping sections between bamboo poles when joined end-to-end, typically expressed as a percentage of the pole length. It ensures adequate strength and load transfer at the joints.

11. **Length of binding wire per joint:** The length of binding wire used to secure each bamboo joint, measured in meters. It depends on the joint type and the required strength of the connection.

12. **Number of nails at a joint:** The number of nails used to reinforce a bamboo joint, typically ranging from 2 to 4 nails per joint. It provides additional strength and stability to the connection.

13. **Number of nails at a lap:** The number of nails used to secure overlapping bamboo sections at a lap joint, typically ranging from 1 to 2 nails per lap. It ensures proper alignment and load transfer between the overlapping poles.

These estimating constants provide essential information for calculating the material quantities and labor requirements for bamboo scaffolding. By accurately determining these constants, project managers can effectively estimate the cost and duration of scaffolding work and ensure a safe and efficient scaffolding process.

## **2.4 Bamboo Scaffolding**

According to (Chung And Siu. (2002), Bamboo scaffolding is a type of

scaffolding made from bamboo and widely used in building work for ages. Many famous monuments such as the Great Wall of China were built using bamboo scaffolding. It was widely used in the building construction of low rise and multi-story buildings (up to four stories high) earlier to the development of metal scaffolding and in the more recent decades have been well advanced in Hong Kong. Bamboo is the fastest maturing grass in the tropical regions of Asia and Africa and is cheap in regions where the plant is locally available. It provides the cheapest scaffolding system in regions with inexpensive semi-skilled labour and abundant bamboo material, (Labour Department 2001).

Ede,(2018),opine that a Quality bamboo has a good tensile and could be used multiple times thereby reducing the cost of construction. It is a fibrous material with verified tensile strength in the range of 156-185 N/mm<sup>2</sup>, which implies a greater strength to weight ratio than steel. Bamboo is also cheaper, making it attractive in poor developing nations. Bamboo scaffold has a renewable resource and can be used effectively for up to 5 story building. But bamboo scaffold is bedevilled with many challenges. Inconsistent bamboo quality can create problems as the actual strength varies with great uncertainty.

Chung and Siu,(2002),Bamboo scaffold design are highly estimated and based more on the capability of the fabricator thereby portending great safety risks. It can be cost effective and quite safe if properly built, but for it to be safe,it must be over designed with more materials therefore tending to be expensive while the urge to cut cost and negligent oversight can lead to

severe fatalities. Accessories for bamboo scaffolding are not customized, does not have a solid footing and anchorage base on the ground, thereby exposing it to a great risk for instability.

#### **2.4.1 MATERIALS FOR BAMBOO SCAFFOLDING**

Bamboo scaffolding is a traditional and eco-friendly construction method used in various parts of the world (R. Chudley et al 2020). It relies on bamboo as the primary material. However, there are additional materials and tools commonly used in bamboo scaffolding to ensure stability, safety, and ease of construction (American Society of Professional Estimators (ASPE) 2020).

Here's a list of materials and tools for bamboo scaffolding:

**Bamboo Poles:** Bamboo is the primary material used for the main structural elements of the scaffold. It provides vertical and horizontal support, acting as the framework for the entire structure.

**Bamboo Cross Braces:** These are shorter bamboo poles that connect the vertical and horizontal main poles to provide additional support and stability to the scaffold.

**Bamboo Lashings:** Natural fibers, such as rattan or nylon ropes, are used to tie and secure bamboo poles together. Lashings are essential for connecting the different elements of the scaffold.

**Bamboo Planks:** Bamboo planks or boards are placed horizontally across the scaffold structure to create a stable platform for workers and materials. These planks can serve as working platforms at different levels of the scaffold.

**Bamboo Nails and Pegs:** Short bamboo sticks or bamboo nails are used to pin or secure bamboo poles and planks together at joints and connections.

**Scaffold Connectors:** Metal or wooden connectors are sometimes used to reinforce and stabilize the joints in bamboo scaffolding. They can enhance the overall strength and durability of the structure.

**Base Plates:** Metal or wooden base plates provide a stable foundation for the bamboo scaffold on the ground. They distribute the load and prevent the scaffold from sinking into soft ground.

**Scaffold Couplers:** These metal components are used to connect bamboo scaffolding with steel scaffolding or other scaffolding materials when transitioning between different construction phases.

**Safety Nets:** Safety nets are often used to provide fall protection for workers. They are secured to the scaffold structure to catch falling objects or personnel.

**Personal Protective Equipment (PPE):** Workers on bamboo scaffolding should wear appropriate PPE, including helmets, safety harnesses, gloves, and safety boots, to ensure their safety.

**Tools:** Various hand tools, including saws, knives, hammers, and drills, are

used for cutting, shaping, and assembling bamboo components.

**Hoists and Pulleys:** For transporting materials and equipment to different levels of the scaffold, hoists and pulleys are often attached to the scaffold structure.

**Debris Chutes:** These are tubes or channels attached to the scaffold to direct waste materials and debris safely to the ground.

**Guardrails and Toe Boards:** Safety guardrails and toe boards are installed along the edges of the scaffold platforms to prevent workers from falling off.

**Access Ladders and Stairs:** For vertical access between different scaffold levels, ladders or stairs are essential.

**Tie-Off Anchors:** These are anchor points for securing safety harnesses and lifelines to protect workers from falls.

**Load-Bearing Platforms:** For supporting heavy loads, such as construction materials, specialized load-bearing platforms are sometimes used.

**Bamboo Mats or Screens:** Bamboo mats or screens may be used to provide shade, weather protection, and privacy to workers on the scaffold.

**Paints and Coatings:** To extend the life of bamboo components and protect them from weathering, various coatings and paints may be applied.

It's important to note that while bamboo is the primary material, the combination of these supplementary materials and tools ensures the safety,

stability, and functionality of bamboo scaffolding in construction projects. Proper installation, maintenance, and adherence to safety standards are critical for the success of bamboo scaffolding systems.

#### **2.4.2 Safety Challenges of Scaffolding**

Ede,(2018), Opine that Safety of scaffolding will depends on the quality of materials adopted and the assembling process. The factory-built steel scaffold system comprising of the tubular sections and the accessories has a definite advantage due to regular shape, engineered design better construction procedure. Bamboo material, on the other hand, has intrinsic size inconsistency with anisotropic compartment. It is less ductile than steel and stands a high risk of being brought down by high wind and overload. The safety risks of bamboo scaffolds is heightened by size variability and strength uncertainty of bamboo material, fittings, design method and construction procedures.

#### **2.4.2 Bamboo Scaffolding in Developing Nations**

According to Olaiya, (2011), Outside Hong Kong, bamboo scaffolding is mostly seen in developing nations of Asian and Africa such as India, Bangladesh, Sri Lanka, Indonesia, Nigeria etc. Tropical rain forest of African and Asian countries are the home of bamboo, which matures to the required

sizes and thickness just in three years. The supply of bamboo is highly sustainable in this tropical scale construction in rural and urban areas. In

fact, bamboo is an essential building and construction commodity in Nigeria due to the abundance from the tropical rain forest. But unlike in Hong Kong, in most these manpower for bamboo scaffolding is evident. In Nigeria, the absence of Government regularization of bamboo scaffolding trade has opened doors to all form of quackery and in many cases leading to frequent fatal accidents and rampant failure of structures under construction.(Ede, 2018).

### **2.4.3 The Hong Kong Experience on Bamboo Scaffolding**

Hong Kong with its largely modern architecture still accommodates bamboo scaffolds for new building and for the renewal of high-rise buildings (Why Hong Kong Prefer Bamboo Over Steel Scaffolding, 2017). Bamboo scaffolding in Hong Kong existed prior to the British colonization of the 1800s.The Hong Kong's success story on bamboo scaffolds was greatly helped by the Government's regularization policy of the bamboo scaffolding trade which led to the abundance of skilled bamboo scaffolders,(Olaiya,2011).

According to HKICM,(2003), The Hong Kong Institute of Construction Managers provided the most trusted specification for bamboo scaffolding. Essentially, easy access to bamboo material, reduced cost and availability of bamboo scaffolding specialists propelled the trade to a great height. Bamboo is easily available from mainland China. In 2013,over 1,751 registered bamboo scaffolders and about 200 scaffolding companies were present in Hong Kong (The Independent,2009).

But in the recent years, the use of bamboo scaffolds in Hong Kong is beginning to diminish due to safety risks, shortages in labour and material.

Construction workers in Hong Kong have one of the highest fatality rate in the developed world. The labour shortage is unconnected to the unwillingness of the youths to take up this trade due to the great accident risks and unsafe work environment.(Why Hong Kong Prefer Bamboo Over Steel Scaffolding, 2017).

#### **2.4.4 Bamboo Scaffolding in Nigeria**

Ede, (2018), In many African countries, notably Nigeria, bamboo scaffolding is still used for small scale construction in urban areas. In rural areas, the use of bamboo scaffolding for construction is common. In fact, bamboo is an essential building and construction commodity in Nigeria; the bamboo materials are transported on heavy trucks and trailers from rural areas (especially the tropical rain forest) to cities and the northern part of Nigeria.

Some of the structures in relaxation and recreation centres, both in urban and rural areas of Nigeria, are put in place using bamboo materials. This is not for reasons of poverty (especially in the cities) but to add more aesthetics to these centres. Bamboo materials are still used in the construction of some bukas (local restaurants) in rural areas (Olaiye,2011).

### **2.5 MANHOUR RATE**

The manhour rate for bamboo scaffolding is a critical component of construction cost estimation, especially in regions where bamboo

scaffolding is commonly used in construction projects (American Society of Professional Estimators (ASPE) 2014). It represents the cost per hour of labor required to install, maintain, and dismantle bamboo scaffolding structures. Understanding this rate in detail is essential for construction project management and budgeting (Jerald Rounds and Robert Segner 2014). Let's delve into the concept of the manhour rate for bamboo scaffolding and explain it comprehensively:

### **2.5.1 Definition of Manhour Rate**

According to(American Society of Professional Estimators (ASPE) 2014) A manhour rate is a unit of labor cost measurement that represents the cost of one hour of work by a single laborer or worker. It includes the laborer's wages, benefits, and other related costs, such as tools and equipment. The manhour rate is fundamental in construction cost estimation as it helps in determining the labor cost component of a project. (Construction Specifications Institute (CSI) 2016).

### **2.5.2 Components of Manhour Rate for Bamboo Scaffolding:**

The manhour rate for bamboo scaffolding comprises several components, which are integral to understanding its overall cost:

**Labor Wages:** The base hourly wage of the scaffolding laborer, which can vary depending on the region and labor laws. It's crucial to consider

prevailing wage rates.

**Benefits and Allowances:** Additional costs associated with labor, including overtime pay, holiday pay, health benefits, and allowances. These vary according to employment regulations and company policies.

**Tools and Equipment:** The cost of tools and equipment required for bamboo scaffolding work, including bamboo poles, lashing materials, safety gear, and other tools specific to bamboo scaffolding.

**Supervision and Overhead:** Costs associated with supervising the scaffolding work, as well as general project overheads such as administration, insurance, and general project management expenses.

**Training and Safety:** Expenses for training laborers in bamboo scaffolding techniques and safety practices to ensure a secure working environment.

**Productivity Factors:** These factors consider labor productivity, efficiency, and any additional time that might be required due to challenging work conditions or technical complexities associated with bamboo scaffolding.

#### **2.5.4 Regional Variation:**

The manhour rate for bamboo scaffolding can vary significantly depending on the region, country, and even the specific location within a region (Barry B. LePatner 2013) . Local labor laws, economic conditions, and the availability of bamboo as a construction resource can all influence the rate. Therefore, it's essential to consider the local context when estimating

manhour rates ( Brian Atkin and Adrian Brooks 2015).

### **2.5.5 Skill Levels and Experience:**

Different skill levels and experience levels among scaffolding laborers can lead to variations in manhour rates. Skilled and experienced scaffolders often command higher hourly wages and may be more efficient, reducing overall labor hours required ( Barry e tal 2013).

### **2.5.6 Project-Specific Factors:**

The manhour rate can also be influenced by project-specific factors, such as the complexity of the scaffold design, the height of the scaffold, the required load-bearing capacity, and the environmental conditions at the construction site. More intricate scaffolding designs or challenging working environments may lead to higher manhour rates (Paul S. Chinowsky 2010).

### **2.5.7 Collective Bargaining Agreements:**

In some cases, labor unions or collective bargaining agreements may govern labor rates in construction projects. These agreements can have a significant impact on the manhour rate, and compliance with such agreements is crucial (Peter Fewings 2007).

### **2.5.8. Cost Estimation and Project Budgeting:**

Accurate estimation of the manhour rate for bamboo scaffolding is essential for project budgeting. It allows project managers to calculate labor costs, allocate resources, and assess the overall affordability of the project. An accurate manhour rate is crucial for ensuring that the project stays within its budget (Brian Greenhalgh 2013).

### **8. Cost Control and Management:**

Monitoring and managing labor costs throughout the project are critical. Project managers need to track labor hours worked and ensure that the manhour rate remains within the established budget (Jerald Rounds et al 2012).

### **9. Legal and Ethical Considerations:**

Ensuring that laborers are paid fair and lawful wages, and that the project adheres to labor regulations, is not only a financial consideration but also an ethical and legal obligation ( American Society of Professional Estimators (ASPE) 2020 ).

In summary, the manhour rate for bamboo scaffolding represents the cost per hour of labor required for scaffolding work in construction projects. It encompasses various components, including labor wages, benefits, tools,

equipment, and overhead costs. Understanding regional variations, skill levels, and project-specific factors is essential for accurate cost estimation and project budgeting. Effective cost control and compliance with labor regulations are integral to the successful management of a construction project employing bamboo scaffolding.

### **3.0 Cost Estimation**

Cost estimating is the meticulous process of assessing and approximating the financial outlay required for a specific project, endeavor, or activity (National Institute of Building Sciences (NIBS) 2017). This method blends scientific data analysis and the art of forecasting to determine the likely financial implications based on the information available at a given point in time.

It's a multifaceted endeavor, involving a variety of stages and estimates:

**Screening Estimate:** This initial assessment, often termed an order of magnitude estimate, takes place before a project is even designed. It relies on historical cost data from similar past projects to provide a ballpark figure.

**Preliminary Estimate:** At this stage, based on a conceptual design, cost estimation becomes more refined. The essential design technologies are known, and a more detailed approximation is possible.

**Detailed Estimate:** The project reaches a point where the scope of work is

distinctly defined, plans and specifications are finalized, and it's ready for construction contractors to bid on it. At this stage, the most precise cost estimate can be generated.

Cost estimating is integral to project management, business planning, and budget preparation. It plays a pivotal role in cost and schedule control, enabling organizations to assess and manage risks and uncertainties effectively. This process essentially serves as the financial compass for an undertaking, informing decision-making and resource allocation at every stage of the project's lifecycle (Derek F. Law and Martin Skitmore 2017).

In essence, cost estimating is the practice of quantifying, predicting, and envisioning the expenses required to construct and equip a facility or execute a project, well in advance of its actual realization.

### **3.1 Techniques to estimate probable construction costs for bamboo scaffolding**

#### **3.1.1 Approximate Quantity Method:**

This method relies on historical data or experience to approximate the quantities of scaffolding materials required for a project. Quantity surveyors typically refer to past projects with similar scaffolding requirements and use their knowledge of scaffolding construction to estimate the approximate quantities of various materials, such as bamboo poles, couplers, planks, and

ropes. Once the approximate quantities are determined, they are multiplied by the current unit rates for each material to arrive at an estimated cost. This method is relatively quick and straightforward, but its accuracy depends heavily on the surveyor's experience and the availability of relevant historical data.

### **3.1.2 Detailed Quantity Method:**

This method involves a more meticulous approach, requiring the preparation of a detailed bill of quantities based on project drawings and specifications. Quantity surveyors meticulously measure and quantify each scaffolding component, including bamboo poles, couplers, planks, ropes, and any additional accessories. These quantities are then multiplied by the current unit rates for each material to calculate the total estimated cost. This method is more time-consuming but provides a more accurate cost estimate compared to the approximate quantity method.

### **3.1.3 Scaffolding Cost Indices:**

Scaffolding cost indices serve as valuable tools for quantity surveyors, providing average cost rates for scaffolding materials and labor in a specific region or country. These indices are typically published by industry associations or government agencies and are regularly updated to reflect current market trends. Quantity surveyors can utilize these indices to estimate scaffolding costs based on the project's location and complexity.

By applying the appropriate cost index to the estimated quantities of materials and labor, they can obtain a more realistic cost projection.

#### **3.1.4 Historical Data Analysis:**

Quantity surveyors can leverage historical data from past projects to estimate scaffolding costs for new projects. This involves identifying projects with similar scaffolding requirements in terms of size, complexity, and location. By analyzing the actual costs incurred in those projects, quantity surveyors can establish a reference point for the current project. This method is particularly useful when dealing with projects that have a close resemblance to previous undertakings.

#### **3.1.5 Expert Judgment:**

Consulting with scaffolding experts or experienced contractors can provide valuable insights into estimating scaffolding costs. These experts possess extensive knowledge of scaffolding construction techniques, material costs, and labor rates. They can provide informed estimates based on their experience and understanding of current market conditions. Quantity surveyors often seek expert judgment to validate their own estimates or to obtain guidance on specific aspects of scaffolding cost estimation.

#### **3.1.6 Computer-Aided Estimating Software:**

Specialized software programs have become increasingly prevalent in the construction industry, offering sophisticated tools for estimating scaffolding costs. These programs often incorporate historical data, cost indices, and algorithms to provide more accurate and efficient estimates. They can automate calculations, generate detailed reports, and even visualize the scaffolding structure in 3D. Quantity surveyors can utilize these software tools to streamline the estimation process and enhance the accuracy of their cost projections.

### **3.1.7 Hybrid Approaches:**

In practice, quantity surveyors often employ a combination of estimation techniques to achieve optimal accuracy. For instance, they might use the approximate quantity method for initial estimates and then refine those estimates using detailed quantities, expert judgment, or computer-aided estimating software. The choice of techniques depends on factors such as project complexity, availability of data, and the desired level of accuracy. Quantity surveyors need to carefully assess these factors and select the most appropriate methods for each project.

In conclusion, quantity surveyors have a range of estimation techniques at their disposal to estimate probable construction costs for bamboo scaffolding. Each technique has its strengths and limitations, and the selection of the most suitable method depends on the specific project context. By carefully considering project complexity, data availability, and

accuracy requirements, quantity surveyors can make informed decisions about the most effective approach to scaffolding cost estimation.

#### **4.0 EMPIRICAL LITERATURE REVIEW**

##### **Murat (2015) - Hydro Electric Power Plants:**

Murat's research focused on developing a cost estimation model for hydroelectric power plant projects. They aimed to determine the feasibility of such projects by considering the amount of energy generated and the associated investment costs.

The cost estimation for the project involved a detailed analysis, including hydrological studies, site investigation, basin planning, geotechnical surveys, and soil testing.

Murat used both multiple regression analysis and artificial neural networks to validate their models. They collected data from 49 hydroelectric power plant projects and used five projects for model validation.

The validation results showed that the neural network model had a prediction accuracy of 5.04%, while the regression model had an accuracy of 9.94%. Therefore, the neural network model proved to be more accurate for cost estimation in this context.

##### **Alfredo (2013) - Construction Projects:**

Alfredo's study focused on an integrated, computer-based approach to estimate costs for new construction projects. They explored the limitations

of computer programs based on parametric estimating methodologies and Case-Based Reasoning (CBR).

The research effectively reused historical data for modeling, which was used in conjunction with the CBR method.

For validation purposes, they selected 17 historical data sets of construction projects. The approach produced detailed and accurate cost estimates for these projects.

This method was found to provide more accurate and efficient cost estimates for construction projects, particularly through automation and CBR problem solving.

#### **Hossein (2012) - Drilling Wells:**

Hossein's study addressed the estimated cost for drilling wells using Case-Based Reasoning (CBR), a method that leverages historical data to solve new, similar problems.

Despite having limited data, the proposed CBR model demonstrated very low error rates in terms of performance indicators, indicating high estimation accuracy.

The CBR method also saved time compared to other estimation methods. Unlike other methods, if a feature didn't have a value, it did not negatively impact the model, contributing to increased drilling speed.

#### **Seokyon (2011) - Time Gaps in Cost Estimation:**

Seokyon investigated the challenges posed by time gaps in construction cost

estimation. Cost estimates often vary due to the timing of the estimation process.

The research developed time series models that accurately predicted changes in construction cost indexes. These models were particularly sensitive to significant cost changes, enabling precise estimation for short-term and long-term periods.

The analysis involved both factor analysis and pattern analysis, and the results demonstrated that the new time series models outperformed existing models, especially when dealing with time gaps.

#### **Kyong (2010) - Genetic Algorithms for Cost Estimation:**

Kyong's research focused on developing a cost estimation model using Case-Based Reasoning (CBR) and Genetic Algorithms for bridge construction projects.

The study utilized genetic algorithms, which are based on principles from genetics and artificial intelligence, to optimize parameter weights.

The application of this method improved the accuracy of early cost estimation models compared to traditional approaches.

The approach was not limited to bridge construction and could be extended to other construction project types.

#### **Sung-H (2006) - Predictive Modeling with Experience:**

Sung-H proposed a model that integrated experience into construction cost estimation using the analytic hierarchy process.

The model aimed to overcome the challenges associated with measuring experience when determining the weights of attributes in cost estimation.

Three different models were compared in terms of efficiency, and the model using the analytic hierarchy process was found to be more accurate, reliable, and explanatory than other models.

The approach leveraged experience from previous cases to solve new problems.

### **Gwang (2004) - Comparing Cost Estimation Models:**

Gwang's research examined the performance of three cost estimation models using data from 530 residential building projects.

The models studied included multiple regression analysis (MRA), neural networks, and Case-Based Reasoning (CBR).

The results indicated that the neural network model provided the most accurate estimation results, while CBR was more effective when considering long-term cost estimation, and MRA performed well in terms of time and accuracy trade-offs.

The study suggested the potential for developing a hybrid model integrating various tools, such as neural networks, CBR, and genetic algorithms.

### **Abdulrezak (2001) - Knowledge-Based System:**

Abdulrezak discussed a knowledge-based system designed for alternative design, cost estimation, and scheduling in construction projects.

The system aimed to integrate cost estimation and scheduling at different

stages of project development, including the redesign and detailed design stages.

Notably, the system was praised for its timeliness and accuracy, making it a valuable tool for value engineering before and after the design stage.

**Tariq (1999) - Time Series Analysis for Productivity:**

Tariq's research focused on time series analysis for evaluating construction productivity.

The paper provided an overview of time series analysis and demonstrated its application using previously published data.

The study showcased the utility of time series analysis in evaluating construction productivity experiments.

**Hojjiat (1998) - Regularization Neural Network for Cost Estimation:**

Hojjiat formulated a regularization neural network architecture for estimating the cost of construction projects, particularly reinforced concrete pavements.

The model was designed to provide consistently reliable and predictable cost estimates, with the result depending solely on the training data and not the network architecture or the number of training iterations.

**Tarek (1998) - Neural Network for Highway Project Costs:**

Tarek's study explored the use of neural networks to estimate project costs, specifically for highway projects.

The research used data from 18 highway projects constructed in Newfoundland, Canada, for training the model./

Instead of using black-box neural network software, a simple neural network simulation was developed in a spreadsheet format familiar to many construction practitioners.

Two techniques, simplex optimization, and genetic algorithms, were used to determine network weights, demonstrating the practicality of using spreadsheet programs to develop neural network models for construction.

### **Alice (1997) - Regression vs. Neural Networks for Cost Estimation:**

Alice's research compared the stability, performance, and ease of cost estimation modeling using regression versus neural networks.

The study found that neural networks were advantageous when dealing with data where the appropriate cost estimation relation was unknown. However, when an appropriate relation was known, regression models outperformed neural networks in terms of accuracy, variability, model creation, and examination.

The neural network model was considered a good alternative when prior knowledge of the appropriate cost estimating relation was lacking.

### **Summary of the related literature review( Gap)**

The reviewed literature encompasses various cost estimation techniques example Approximate quantity method, Detailed Quantity Method,

Scaffolding Cost Indices, Historical Data Analyst, Expert Judgement, Computer-Aided Estimating Software and Hybrid Approaches. However, these Existing estimation techniques used by estimators to estimate probable construction costs are unreliable and lack precision, making them unfit for contractual purposes. Developing an accurate cost estimation method specifically for scaffolding would greatly assist estimators in managing costs. .Therefore, a specific formula for calculating preliminary works is crucial, as these works form an integral part of the overall contract sum.

## **CHAPTER THREE**

### **RESEARCH DESIGN AND METHODOLOGY**

#### **3.0 INTRODUCTION**

This Chapter expound the various process adopted by researcher in carrying out the research survey for developing equations on Bamboo scaffolding

projects around building, and data collection for the process followed by the researcher to find facts. It also expounds the principle techniques that are used to perform the activities involved.

### **3.1 AREA OF STUDY**

The following statement among others would make for an acceptable discussion under this study area. The study will be undertaken in Awka south local Government Area of Anambra State. The state is situated in the south eastern part of Nigeria.

The boundaries are formed by Kogi State to the north, Enugu State and Abia State to the east. Rivers and Delta State to the west.

### **3.2 SOURCES OF DATA COLLECTION**

Our research takes a comprehensive approach, relying on both primary and secondary data sources to ensure a rich and reliable pool of information.

#### **3.2.2 Primary Source of Data**

We collected primary data through structured interviews with scaffolders and traders in Awka, Anambra State, who are directly involved in the scaffolding industry. These interviews provided valuable insights and firsthand perspectives.

### **3.2.3 Secondary Source of Data**

Secondary data was gathered from various sources such as journals, articles, websites, and textbooks that discuss cost estimation modeling, bamboo scaffolding, and cost modeling. We accessed these materials from the school library, Anambra State Library, and online databases.

### **3.3 RESEARCH DESIGN**

According to (William 2006) The research design refers to the overall strategy that you choose to integrate the different components of the study in a coherent and logical way, thereby ensuring you will effectively address the research problem; it constitutes the blueprint for the collection, measurement and analysis of data. Note that your research problem determines the type of design you can use, not the other way around!

Also, ( Shona 2019) stated that research designn is a framework for planning your research and answering your research questions. Creating a research design means making decisions about: The type of data you need, The location and timescale of the research, The participants and sources, The variables and hypothesis ( if relevant )and The method for collecting and analyzing data. The design used by researcher is Algebraic Manipulation.

### 3.3.1 Algebraic Manipulation

Algebraic manipulation is a fundamental concept in mathematics that involves transforming algebraic expressions into equivalent forms without changing their underlying meaning or value. It is a crucial skill for solving equations, simplifying expressions, and analyzing mathematical relationships.

Algebraic manipulation encompasses a variety of techniques, including:

**Expanding and Factoring:** Expanding involves multiplying out terms within parentheses or brackets, while factoring involves breaking down expressions into simpler components.

**Combining Like Terms:** Like terms are those that have the same variables raised to the same powers. Combining like terms involves adding or subtracting them to simplify expressions.

**Applying Algebraic Laws:** Algebraic laws, such as the commutative, associative, and distributive laws, provide rules for rearranging and manipulating expressions without altering their value.

**Solving Equations:** Algebraic manipulation is essential for solving equations, which involves isolating the variable of interest and determining its value.

**Simplifying Expressions:** Simplifying expressions involves using various techniques to reduce them to their most concise and manageable form.

### **3.4 POPULATION SIZE**

Our research focused on a population of 20 individuals, consisting of 10 traders in scaffolding materials at the Umuokpu Awka building materials market and 10 practicing scaffolding contractors in Awka. This diverse group brought expertise from various angles of the scaffolding industry.

### **3.5 SAMPLE SIZE**

Considering the relatively small population, we carefully selected a representative sample of 20 individuals, including 15 traders and 5 scaffolders. This sample size allowed us to collect and analyze data effectively.

#### **3.5.1 SAMPLING TECHNIQUE**

The sampling technique adopted for this study is simple random sampling. Simple random sampling is a sample in which each unit in the population has an equal chance of being selected and this method of sampling is wholly free from bias. In order to ensure that the data be used are of high reliability, they were fetched from good practicing construction industry.

### **3.6 METHOD OF DATA ANALYSIS**

We analyzed the collected data rigorously using algorithmic equations and simple fractions. These techniques helped us develop a robust cost estimation model specifically for bamboo scaffolding. This ensured the validity and reliability of our model.

### **3.7 INTERVIEW**

Structured interviews were conducted with selected participants to collect primary data. We prepared a set of written questions aligned with our research objectives. These face-to-face interviews allowed us to delve deeply into the knowledge and experiences of the participants, giving us a comprehensive understanding of the cost dynamics in the scaffolding industry.

#### **3.7.1 TRANSCRIPTION OF INTERVIEWS**

We conducted interviews in two phases.

In the first phase, we visited scaffolding contractors on-site and conducted interviews to gather data on material requirements, labor output per day, and labor costs.

In the second phase, we surveyed the building material market in Umuokpu Awka, Anambra State. This helped us determine the unit costs of materials

used in bamboo scaffolding. We interviewed traders who dealt with these materials. The information collected from these interviews is presented in the following tables.

Table Material Report

S/n	Materials	Unit	Type	Size	Length	Unit Cost
1	Bamboo	nr	oxytenanthera obyssinica (Male bamboo )	40-75mm diameter and min.of 10mm thick	9- 9.6 metres (30-32 feet)	N750
2	Nail	kg	Ordinary steel nail	6 inches	19 pieces per kg	N400
3	Binding wire	kg	mild steel wire	1mm diameter	520 metres for 20 kg (1 roll).	N22000

Table Model

S/N	Objectives	Source of Data	Type of Data	Tool for Data Analysis
1a	Quantity of bamboos materials required.	Architectural drawing	Primary data	Algorithmic Equation
2a	Unit cost of materials	Traders	Primary data	Simple fraction
3	Unit cost of labour	Scaffolders	Primary data	Simple fraction

