Identification of factors on the possibility of bamboo as a scaffolding and a formwork material in Ethiopia

Ermias A. Amede, Ezra K. Hailemariam, Leule M. Hailemariam and Denamo A. Nuramo

Abstract: From several countries trend bamboo has been used as a scaffolding material in building projects. Nonetheless, Ethiopia is known for the high population of bamboo vegetation such utilization of the material remained untapped. The purpose of this paper is to identify factors that influence bamboo's structural suitability as a temporary material and to create a conceptual map for using it as an alternative structural material. Following the identification of important applications influencing parameters via literature analysis, both qualitative and quantitative approaches were used to identify significant factors. The paper also used a series of protocols; at first, several documents were selected based on criteria to provide an overview of bamboo-based construction systems. Following that, four major categories for SWOT analysis were chosen to examine the Ethiopian construction industry's stance on the use of bamboo as a scaffolding material. Finally, a scoring model was employed as a quantitative analysis protocol to calculate the weight of factors (safety, procedure and implementation, time, and cost) through expert opinions. The investigation revealed that the use of bamboo has a cost and time savings advantage, while an increase in trash at acute and intermittent areas was one of the challenges. Furthermore, one of the challenges in creating bamboo formwork is a lack of complementary joinery techniques. Besides that, it is expected that the bamboo content will fall short of technical requirements. On the Brightside, every single respondent stated unequivocally that bamboo-made formwork meets a low-cost requirement.

Keywords: Biomaterials; Biomaterials & Medical Devices; Structural Engineering

1. Introduction
In recent periods, Ethiopian construction industry undertakings are being carried out by government and private firms that consume large quantities of non-renewable resources (Durdyev & Ismail, 2012). Most of these construction activities involve the Eucalyptus tree, a non-renewable natural resource, as

PUBLIC INTEREST STATEMENT

Bamboo is a tough, fast-growing, and long-lasting material. It can be an aesthetically beautiful and low-cost alternative to more traditional materials in modern times. Despite the literature's recognition of bamboo's great potential as a resilient, sustainable scaffolding and formwork material for structural element design, its use in Ethiopia remains untapped. This is mostly owing to the scarcity of globally applicable standards and rules to guide or aid in the development of joinery techniques and elements. As a result, bamboo's use as a scaffolding and formwork material was mostly based on established practical traditions, forefathers' intuitions, and engineering knowledge. The purpose of this article is to identify and consider road maps and methods for using bamboo as scaffolding and formwork materials.
a scaffolding and formwork material. As a result, timber stock is fast-dwindling, and there is an increasing difficulty in getting timber. In addition, the cost of timber products is overpriced and difficult to afford. This demand creates a considerable gap between demand and supply, threatening Ethiopia’s remaining meager forest resources. On the contrary, using environmentally friendly and sustainable building materials promotes the local conservation of declining timber resources.

Bamboo grows in the tropical rain forests of African and Asian countries, with abundant vegetation (Gatóo et al., 2014). Because of its lightweight, great flexibility, speediness, and cost-effectiveness, bamboo has been used as a scaffolding material and small-scale construction in some regions (Bambhava et al., 2013; Fang et al., 2004). Nevertheless, some countries have utilized such material as for scaffolding its application is limited due to the absence of codification and standardizations (Amede et al., 2021; Gatóo et al., 2014). In addition, in most of these developing tropical nations, the absence of government regularization, a legal framework for the trade, and skilled human resources for bamboo scaffolding have opened doors to frequent fatal accidents and rampant failure of structures under construction (Ede et al., 2018). Despite the abundant bamboo population in Ethiopia, such resources remained untapped and limited to utilizing small-scale houses, fences, some ordinary furniture, and household utensils. Hence, this study aimed at developing a conceptual road map to use the material as an alternative construction material after identifying the factors that affect the applicability and adaptability of bamboo utilization as a scaffolding material.

2. Review of the literature

2.1. Scaffolding

A scaffold is a temporary structure used to support people, materials, and systems under construction and maintenance. It is indispensable for different processes in a building project (R. Wong, 2015). It presents an essential part in construction especially building operations at height. It is used in new construction, alteration, routine maintenance, renovation, painting, repairing, and removal activities. Scaffolding offers a safer and more comfortable work arrangement than leaning over edges, stretching overhead, and working from ladders. Scaffolding provides employees with secure access to work locations, levels, stable working platforms, and temporary storage for tools and materials to perform immediate tasks (United States Department of Labor, 2016).

Generally, scaffoldings are categorized based on how the structure interacts with the building it’s up against, how it’s constructed, and the type of weight it can support. Based on how scaffoldings are built, they can be classified as follows (Table 1):

2.1.1. Bamboo as scaffolding materials

In Southeast Asia, especially in Hong Kong bamboo has been utilized as a scaffolding material for many years. Due to their high versatility and adaptability utilization of bamboo for a scaffolding purpose in irregular architectural features was achieved with a comparatively short period of time (Chung & Chan, 2002). Bamboo scaffolding is also cheaper in the regions as there are inexpensive needs semi-skilled labor, and abundant bamboo material where the plant is locally available.

According to several literary works, bamboo has been labeled as a suitable replacement of wood due to its adaptability in a variety of ecological environments, its ability to repair soil devastation, its ripeness to be harvested after 3 to 5 years of plantation (Amede et al., 2021), it’s capacity to produce a cost-efficient, high-quality bamboo culm suitable for use as a wood supplement, and its versatility possessing high strength-to-weight ratio which offers considerable ease in working with more straightforward tools. Furthermore, several studies have proved and indicated that bamboo could be used for more than just housing construction. It can also be used for bridges, scaffolding,
Table 1. Types of scaffolding systems based on how they are constructed

| Type               | Support               | Feature               | Specific use                                      | Forms                                |
|--------------------|-----------------------|-----------------------|--------------------------------------------------|--------------------------------------|
| Supported scaffolding | Base upwards roof or other tall construction | Most common high efficiency | Permanent access to elevated positions is not possible to construct a base | - Tube and coupler scaffolds - Frame or fabricated scaffolding - Systems scaffold |
| Suspended scaffolding | Movable               | Semi-permanent        | Rapid movement                                   | manual and electric.                |
| Mobile scaffolding  | Movable               | Semi-permanent        | Ease access                                      | Manual                              |
| Aerial lifts       | Truck-mounted         | Access several levels | Access to two or more floors, at different times | -                                   |

Source: (United States Department of Labor, 2016)

Bamboo reinforced concrete, bamboo-based panels, and aesthetical purposes in modern building constructions (Amede et al., 2021; Fang et al., 2004; Gatoo et al., 2014; Sharma et al., 2015).

However, in most of these developing tropical nations, the absence of government regularization, a legal framework for the trade, and a skilled workforce for bamboo scaffolding have opened doors to frequent fatal accidents and rampant failure of structures under construction (Fang et al., 2004; Gatoo et al., 2014). Unlike some Asian countries with requirements for designing bamboo scaffolding, Hong Kong, for example, (Hong Kong Institute of Construction Managers, Limited, 2003), scaffolding construction manuals are hardly available. And in most cases, the fabrication is undertaken by people with unverified experience and no certification, lacking sound engineering principles. The quality can only be verified by visual inspection, and the accessories needed for installation are commonly invented based on the fabricator’s intuition.

With this approach, it becomes evident that the risk of building collapse due to bamboo scaffolding collapse is inevitable. The safety risks of bamboo scaffolds are heightened by size variability and strength uncertainty of bamboo material, fittings, design method, and construction procedures. It is less malleable than steel and risks being brought down by high wind and overload. This scenario intensifies, especially in the rainy season, which is more prone to rainstorms overloading bamboo scaffolds. Where predominant failure of scaffolding systems is recorded (Ede et al., 2018; Fang et al., 2004). To avoid this, scaffolding must be tied to the building and pre-fixed to concrete at each floor for multi-story constructions. Support between the building and the scaffolding is also necessary to prevent the scaffolding from tilting towards the structure. However, bamboo scaffolding accessories are not tailored, and it lacks a firm grounding and anchorage base on the ground, putting it at risk of instability. As a result, due to safety concerns, the use of bamboo scaffolds is declining.

2.1.2. Attributes for scaffolding selection

Bamboo scaffolding is increasingly competing with steel scaffolding, an industrial product with standardized specifications that can be quickly erected and dismantled. It is a natural material, unlike steel, and hence its strength is not consistent. Because of its uniform shape, engineered design, and more straightforward assembly technique, the factory-built steel scaffold system, consisting of tube sections and accessories, has a distinct advantage. It also surpasses bamboo scaffolding because it is simple to assemble, satisfying uniformity, automation, and safety construction demands. Bamboo, on the other hand, has a natural irregularity in size. As a result, metal scaffolding lags behind its competitors (Fang et al., 2004). Figure 1 depicts the factors and techniques that must be considered when choosing bamboo as a scaffolding material, with two categories, specifically fabricated products, and naturally utilized bamboo culms, under basic consideration factors such as safety, cost, time, and operation & application. Before choosing the scaffolding, several factors must...
Figure 1. Bamboo scaffolding selection platform.

| PERFORMANCE MEASURES | DEFINING PARAMETERS | NATURAL | FABRICATED |
|-----------------------|----------------------|---------|------------|
| COST                  | Initial Cost         | +       | -          |
|                       | Maintenance Cost     |         |            |
|                       | Accessories          | -       |            |
|                       | Storage              | -       |            |
|                       | Labor                |         |            |
|                       | Wastage & disposal   | -       |            |
| TIME                  | Floor cycle Duration | +       | -          |
|                       | Construction         |         |            |
|                       | Delivery             | -       |            |
|                       | Preparations         | -       |            |
|                       | Dismantle            | -       |            |
| SAFETY                | Physical Property    | +       | -          |
|                       | Mechanical Property  |         |            |
|                       | Grade of material    | -       |            |
|                       | Accident rate        | -       |            |
| OPERATION & APPLICATION | Design              | +       | -          |
|                       | Preparation          |         |            |
|                       | High rise building   | +       | -          |
|                       | Acute areas & Irregularities | |            |
|                       | Humid areas with long period | |            |
|                       | Environmental effect | +       | -          |
|                       | Flexibility          | +       | -          |
|                       | Easy of configuration|         |            |

- Initial cost is cheap
  A typical piece of bamboo is only about 60% the cost of a similar length of steel scaffolding.

- Maintenance cost is high

- Reused for many times
  Cost difference will be leveled out when more and more projects are taken into consideration.

- Manually handled
  It is estimated that erecting of bamboo scaffolding is about six times faster, and the dismantling of bamboo scaffolding about twelve times faster than metal scaffoldings.

- Increased cycle time
  Construction of metal scaffolding requires machinery and sophisticated hand tools.

- Affected by moisture content
  Bamboos come from different species and mature in different period therefore they poses different mechanical and physical properties which makes them difficult to standardized or configure their design.

- Consistent physical and mechanical property

- Unpredictable Property

- Easy to configure

- Greater lead way

- Rigid Procedure

- Light but susceptible to wind

- Heavy dead load to move the scaffold

- Increased wastage & difficult to erect

- Might not perfectly fit to standard

- Absorb moisture and decompose

- Stat for a long time

- Promotes deforestation

- Co2 emission
be considered when calculating costs, such as labor usage, accessories, storage, and waste and disposal. In terms of time, the most important consideration is floor cycle duration, which includes aspects such as delivery, preparation, construction, and dismantling. Another important factor to consider is safety; under safety, it is important to study the physical and mechanical properties of the material before using it for scaffolding purposes. During the safety consideration phase, the grade of the material and the accident rate should be anticipated. Finally, the operation and application factor falls under the specific subcategories of design and preparation of several application perspectives, which means that the operation and application of the material must be considered separately for high rise, irregularly shaped buildings, as well as several environmental factors.

2.2. **Formwork**

Formwork is a temporary structure that keeps fresh concrete in place until strong enough to support its self-weight. It is a self-supporting structure capable of bearing both a dead load of reinforcement and fresh concrete and the living load of equipment, personnel, and other materials. Vertical Systems (wall and column) and Horizontal Systems (floor and ceiling) are the two types of formwork systems (slab and beam). The sheathing is the material that serves as the form’s contact face and is utilized in both vertical and horizontal systems.

After the concrete and reinforcement bars, it is the most significant ingredient in concrete building (Baxi, 2011). This is because it shapes and molds the concrete to the desired size and shape while maintaining its position and alignment control. Poor form joints, offsets, or facing material all indicate poor form quality. In this regard, because it accounts for a large portion of the entire project cost of the concrete structure (ACI, 2004), it has a significant impact on the success of a construction project in terms of speed and quality cost, and work safety. As a result, forms’ functional and financial contributions to the entire concreting process cannot be overlooked, and they require the same level of attention as permanent materials.

2.2.1. **Parameters for formwork selection**

Any structural design philosophy provides a cost-effective and appropriate structure capable of handling the required load without jeopardizing the intended purpose. To accomplish this, structures are designed with either ultimate limit states or serviceability limit states in mind. This study employs the ultimate limit state design, which considers the limit state beyond which the members become unsuitable for their original purpose, as demonstrated by the serviceability limit state.

The scaffolding system is intended to function as a single unit. Its constituent members, such as posts, ledgers, and other structural parts, are laid out as a single, sturdy framework. As a result, each structural member must be sufficiently robust to withstand the effects of applied load during service without jeopardizing the safety of other components. In general, the ultimate limit condition refers to the safety of a complete or portion of the structure before failure. The ultimate limit state capacities and resistances determined in this study are set as limiting values for structural adequacy and safety. The purpose of the design is to reach these limits in vertical and horizontal parts of the scaffold to adopt a layout that achieves maximum structural efficiency and obtains the best combination of members and quality, consistent with the scaffold’s overall requirements. The type of formwork used and erected on construction sites are among the most essential aspects in determining a construction project’s success in cost, quality, construction speed, and project safety (R. Wong, 2015). Formwork must accomplish a mix of technical, functional, and economic needs to successfully carry out its purpose (The Constructor, 2021); figure 2 demonstrates a framework for formwork selection.

2.2.2. **Temporary structures safety**

Even though safety is a fundamental human requirement, it is difficult to achieve in construction projects. Due to increased safety concerns and cost-effectiveness in construction projects,
Figure 2. Framework for formwork selection.

KEY FACTORS

| REQUIREMENTS | SELECTION FACTORS |
|--------------|-------------------|
| COST         | Low cost material |
|              | Low cost energy   |
|              | Low cost labor    |
|              | Repetitive use    |
|              | Care and maintenance |
|              | Unskilled or semi-skilled labor |
| TIME         | Speed of erection |
|              | Speed of dismantling |
|              | Fixing method     |
|              | Location of work  |
|              | Actual site condition |
| SAFETY       | Ease of handling  |
|              | Adjustments       |
|              | Leveling          |
|              | Striking without damage |
|              | Access for placing |
| QUALITY      | Containment       |
|              | Strength          |
|              | Resistance to leakage |
|              | Accuracy          |
|              | Rigidity          |
|              | Finish and reuse potential |

Cost of formwork include material, cost of cutting, material wastage, labour to assemble and erection, striking and transportation of formwork panels, replacement of reused panel.

If a form work system is not appropriately designed (if there is wrong selection, inefficient fixing method, difficult location of work, more labour intensive) to fit the actual site conditions, it will have low efficiency and affect the speed of work.

In formwork construction dangers usually occur due to work at height, heavy hoisting equipment, unstable form work and congested working area.

Quality of concrete can be affected by dimensional accuracy of the form work; the verticality, leveling or alignment of the form work; the tightness of joining of the panels and whether the panel surfaces is in good condition.
particularly for high-rise buildings, materials for shoring and scaffolding have changed dramatically. In this sense, the conventional wooden poles and bamboos system is unsuitable and fails to meet any safety standards. For years, there have been complaints of bamboo scaffolding-related accidents, according to documents. A survey by (Bambhova et al., 2013) showed that 42 % of the respondents have no confidence in bamboo scaffolding. The volatile property and safety aspect of this traditional method desperately needs deeper examination. There is a need to make a great deal more to improve the safety of bamboo scaffolds, despite the steady improvements over the past decade. Regardless of its merits, the local application of bamboo scaffolding has inevitably been a controversial issue in building construction.

3. Methodology

3.1. Qualitative approach
For the first part of the research, a qualitative method is used. This is because of the flexibility offered in all aspects of the research process. It is more appropriate to explore the nature of a problem or phenomenon without quantifying it (Gounder, 2019).

3.1.1. Document analysis
For the set forth aim of the research to elicit meaning, gain understanding, and develop empirical knowledge (Bowen, 2009); a thorough document analysis was employed. The documents used for systematic evaluation as part of a study are mainly journals, organizational and institutional reports of local studies. These documents provide data on the context in which research participants operate a text giving context that provided background information that assisted the researchers in understanding the specific issues and conditions that influence the phenomenon currently under investigation. In addition, these documents provide a means of tracking change and development (Table 2).

| Table 2. Description of document form used for document analysis |
|---------------------------------------------------------------|
| **Name of the document** | **Document form** | **Reference** |
| 1. Assessment of Assosa bamboo (oxytenanthera Abyssinica) as an alternative scaffolding material | Paper | (Hassen, 2015) |
| 2. Bamboo Resources in Ethiopia: Their value chain and contribution to livelihoods | Journal | (Mekonnen et al., 2014) |
| 3. Ethiopia-Bamboo-Policy-Integration-Analysis | Working Paper | (Minale & Abebe, 2020) |
| 4. Ethiopian Bamboo Development Strategy and action plan | Institutional report (EFCCC) | (EFCCC, 2020) |
| 5. Opportunities and Challenges in the Ethiopian Bamboo Sector: A Market Analysis of the Bamboo-Based Value Web | Journal | (Lin et al., 2019) |
| 6. The Indigenous Bamboo Forests of Ethiopia: An Overview | Journal | (Embaye, 2000) |
| 7. Value chain analysis and market assessment of Bamboo products in Ethiopia | Institutional report (INBAR) | (INBAR, 2018) |
3.1.2. SWOT analysis
According to the study of (Gulam, 2019; Gürel, 2017; Ommani, 2011), SWOT analysis is a useful technique to help researchers bring a clearer common understanding of factors for successful identification and decision-making. Hence, a SWOT analysis technique was employed to analyze and identify the possible organizational and environmental factors for selecting and utilizing bamboo as scaffolding and formwork. The analysis has two features: internal and external. Interior characteristics factors are strengths and weaknesses within an organization. On the other hand, the external feature includes threats and opportunities within the environment. Furthermore, the SWOT MATRIX identifies potential tactical strategies that could be deployed to capitalize on opportunities or defend against threats by leveraging existing strengths and reducing weaknesses. After completing the SWOT analysis, each point was labeled as: a) items that must be addressed immediately; b) items that can be handled now; c) items that should be researched further; and d) items that should be planned for the future.

3.1.3. Expert opinion
Evaluation and opinion of competent and experienced experts on a subject matter become the basis for adopting serious decisions, including implementing innovation recommended by a researcher to obtain necessary results (Iriste & Katane, 2018).

In this paper, the expert’s opinion was employed to; a) create forecasts if the information about the object of the research is not available or it is not exact; b) create forecasts if the forecasting object is new and there is not any equivalent available; c) describe in detail main requirements of the research method, explain the procedure of the research, select methods and types of obtaining and processing data; d) evaluate the validity of surveys and adjust surveys at a large scale; e) analyze in detail the results and forecast changes of the psychological and pedagogical phenomenon of the research; f) confirm and revise data obtained using other methods; g) clarify factors influencing the development of the object of the research included in the models; h) analyze the results, mainly, if there is an opportunity to have different interpretations.

4. The selection of experts and its principles
The accuracy and dependability of an expert’s judgment are highly influenced by personal bias and can be subjective. Hence it is important to select experts carefully (Malisiovas, 2010). Not each professional of the industry, including a competent schoolteacher or a member of academic staff, a scientist is eligible to be a qualified expert because experts need analytical and strategic thinking, forecasting ability, ability to look from a different angle at the object or a problem of the research (Mikecz, 2012). The experts for this article were chosen using the selection principles of (Mikecz, 2012) like; a) The expert’s area of competence should be reflected; b) Professional activities should be relevant to the research problem, either directly or indirectly; c) Experts should not be involved directly in the planned implementation of innovations. In addition, the study included additional expert selection criteria, i.e., both academic and industry experts should be included.

4.1. Quantitative approach
4.1.1. Scoring model
A quantitative assessment using scores and weights for all attributes on the adaptability of a bamboo scaffolding was provided; this method justifies its importance because a) The model provides a quantitative measurement of the overall performance of a bamboo material based on given sub-criterion; b) The simplicity and the fact that it does not require the use of any unique formulas or complex mathematical calculations; c) The type of data collected to perform the evaluation is simple and easy to obtain; d) It takes into consideration the different degrees of importance for the different attributes in the evaluation process, and hence, gives more accurate
results; and e) It is flexible in the way the tables are formed and gives complete freedom in choosing the attributes to be included in the evaluation.

4.2. Procedures of a scoring model

A couple of criteria were selected based on which the different ideas will be scored. The total score is calculated utilizing a simple or a weighted sum. This final score can be used to prioritize the next stage (Portofolio Management Scoring Models, 2021).

Step 1—Define criteria:—Four standards (Safety, Operation, and Application, Time, and Cost) are available. These classifications are split into multiple sub-criteria.

Step 2—Provide the criteria with a certain weight, where the sum of all weights equals one. The consequences reflect the priority (Table 3).

As listed on the above Table 3, each of the characteristics and attributes, the following parameters were calculated:

Score: The scoring model will use the following terminology to describe the score of the bamboo scaffolding attribute against each criterion: “1”: Have an adverse negative impact—Represented by \(-100\) for magnitude and \(0\) for significance; “2”: Have a slightly negative effect—Represented by \(-50\) for magnitude and \(25\) for significance; “3”: Have no impact at all—Represented by \(0\) for magnitude and \(50\) for significance; “4”: Have a positive effect—Represented by \(50\) for magnitude and \(75\) for significance; “5”: Have an extremely positive impact—Represented by \(100\) for magnitude and \(100\) for relevance.

Weight: a percentage value (out of 100%) used to express the degree of importance of each attribute in respect to the specified sub characteristic set examined in the evaluation criteria. This value will be assigned to each feature on the basis that the sum of the weight for each sub characteristic set should equal 100, that is, the total weight of each table should equal 100%.

Relative weight \(X\): the weight associated with each sub characteristic set concerning the selected evaluation criterion (the total weight in each characteristic set).

Relative weighted score \(Y\): the sum of the weighted scores of each character set.

Weighted score: the score of each sub-criteria against each attribute, multiplied by the degree of importance of each point. This is calculated according to the following formula.

\[ \text{Weighted Score} = \text{Score} \times \text{Weight} \]

The final equation describes the total weighted score of the bamboo scaffolding considering the examined criteria.

\[ C = A \times m + B \times n + C \times o + D \times p \tag{1} \]

where:

\(C\): The total weighted score of the suitability of bamboo scaffolding

\(m\): The relative weight of the Safety
### Table 3. Selected criteria and sub characteristics for scoring model analysis

| Criteria                  | Sub characteristic                                                                 |
|---------------------------|-------------------------------------------------------------------------------------|
| Safety (40%)              | Sub characteristic 1: A bamboo scaffold is prone to collapse due to a strong wind. |
|                           | Sub characteristic 2: The maximum buckling strength of bamboo scaffolding may not be assured |
|                           | Sub characteristic 3: The structure of the bamboo scaffold relies on the strength and quality of each piece due to the variation in size and its mature lifetime |
|                           | Sub characteristic 4: Bamboo is a natural material, and it expands and contracts as the moisture content changes |
|                           | Sub characteristic 5: Bamboo scaffolding is not suitable for high-rise buildings since the wind load increases as the height of the building increases |
|                           | Sub characteristic 6: The safety of bamboo scaffolding mainly depends on the judgments of the worker. |
|                           | Sub characteristic 7: Bamboo scaffolding poses different mechanical and physical properties; hence it's difficult to make them standardized or configure their design. |
| Operation and Application (20%) | Sub characteristic 1: There is an increased wastage of bamboo scaffolding in acute and irregular areas |
|                           | Sub characteristic 2: Bamboo scaffolding is prone to moisture and consequent decomposition |
|                           | Sub characteristic 3: The use of bamboo scaffolding promotes deforestation |
|                           | Sub characteristic 4: Differences in the skills of each individual can weaken the quality of work in bamboo scaffolding |
|                           | Sub characteristic 5: Bamboo cannot withstand the strong wind pressure at high levels |
|                           | Sub characteristic 6: Bamboo scaffolding for high-rise building projects has the advantage of being light |
|                           | Sub characteristic 7: Bamboo scaffolding can be cut to exact measurements based on the site situation |
|                           | Sub characteristic 8: Recycle bamboo can be recovered from its use as scaffold material into useful intermediate raw material |
| Time (20%)                | Sub characteristic 1: The bamboo scaffold deforms after its erection and requires constant rectification |
|                           | Sub characteristic 2: Frequent inspection is required to ensure the structural integrity of the bamboo scaffolds after the scaffolding system is erected |
|                           | Sub characteristic 3: Preparation before the commencement of work is not necessary for bamboo scaffolding |
|                           | Sub characteristic 4: The construction of bamboo scaffolds has a greater lead way than metal bamboo |

(Continued)
### Results

5.1. **Bamboo scaffolding**

A SWOT analysis was used to identify the major constraints and opportunities in the bamboo sector. This provides an overview of where the industry is at the moment. Internal investigation helps to discover strengths and weaknesses, whereas external analysis concentrates on environmental challenges and possibilities. It also aids in determining which resources and competencies are more likely to provide competitive advantages and which are less likely to do so. The investigation focused on four primary topics. The targeted areas were valued chain and market assessment, investment incentives, and value addition, bamboo in construction and research Support, and timber substitute and resource management: As shown in Figures 3-6; the target areas strength, weaknesses, opportunities, and threats are indicated on the top left, top right, bottom left, and bottom right corners, respectively.

1. **Value chain and market assessment:** Ethiopia has one of the largest bamboo populations in Africa. Ethiopia is now only a minor player in the global bamboo trade (INBAR, 2018). As a result, it is critical to identify key variables and conditions that facilitate or obstruct the incorporation of bamboo policy and programming into national development plans and goals (figure 3).

2. **Investment incentives and value addition:** Bamboo has been incorporated into national development plans and strategies, such as green growth strategies and climate change plans, which are at the heart of the country’s sustainable development plans (Minale & Abebe, 2020). The Ethiopian government prioritized the development of the bamboo industry in GTP II. The national forest policy, as well as the conservation and usage proclamation for forest development, all emphasize the importance of bamboo. Bamboo is being promoted as a valuable species in the

| Criteria | Sub characteristic |
|----------|--------------------|
| Cost (20%) | Sub characteristic 1: A bamboo scaffold is the most economical |
| | Sub characteristic 2: The maintenance costs of bamboo scaffolds are expensive |
| | Sub characteristic 3: Score the different criteria |
| | Sub characteristic 4: Calculate the total score based on the scores of the individual criteria and their assigned weights |

n: The relative weight of the Operation and Application

o: The relative weight of the Time

p: The relative weight of the Cost

A: Relative weighted score for Safety

B: Relative weighted score for Operation and Application

C: Relative weighted score for Time
areas of poverty alleviation, job creation, climate change adaptation and mitigation, green economic growth, and land rehabilitation and restoration. By the end of 2030, Ethiopia will be Africa’s largest high-value bamboo producer and supplier. In the country’s 2016–2020 Growth and Transformation Plan, bamboo is an important species for livelihood development and environmental rehabilitation (figure 4).

3. Bamboo in construction and Research Support: Even though bamboo holds great promise as an alternative material that can be added to the local construction resource list due to its abundance, rapid renewability, and high mechanical qualities (Hassen, 2015), it is widely used as an interior and exterior decorative material for rural-dwelling units, urban housing units, and ecotourism resorts. Bamboo is primarily used in Ethiopia to build fences and houses, as well as agricultural utility products, furniture, fuelwood, feed, and fodder. In recent years, a few businesses have begun to develop industrial bamboo products such as parquet flooring and bamboo-stick-based items. However, due to a lack of technology and a trained workforce on treatment methods and construction techniques, as well as a poor perception of bamboo as a less durable...
material, the use of bamboo as a modern construction material, such as for whole-culm-based housing material and bamboo industrial or engineering product usage, has not increased. In general, there is a substantial amount of research-based material available, but technical information has not been adequately shared across the bamboo sector. There is a lack of reliable and consistent data on the state of the bamboo resource base, as well as policy options for sustainable bamboo resource development (figure 5).

4. Timber substitute and resource management: Bamboo is one of Ethiopia’s most important non-timber forest products (NTFP), contributing an estimated 56,250,000 Ethiopian Birr to GDP and
employing 750,000 people. Bamboo utilization has increased in recent years, and it is now the primary wood alternative for rural and urban house construction in Ethiopia. Although bamboo is a flexible material with proven applications in higher value addition technologies and a huge potential to bring triple bottom line benefits (social, economic, and environmental), it is under-utilized (figure 6).

The SWOT Matrix seeks to develop tactical strategies based on four different positions (figure 7).

1. **SO strategies**—Taking advantage of external opportunities by leveraging a company’s internal capabilities.
5.1.1. Leverage

A general lack of policy has resulted in the bamboo sector’s underdevelopment, which has hampered its development. Training and capacity-building activities that aim to add value are merely for show. Farmers are trained in facilities, but when they return home, the necessary infrastructure is not available.
Figure 7. SWOT matrix.

| SWOT Matrix |
|-------------|
| Unequal distribution of bamboo in different regions of the country | There is lack of standards and understanding of the potential mechanical qualities. |
| Large raw material base existences in Ethiopia | The structural potential of bamboo can be learned from the experience gained from south Asian countries |
| High capital and advanced technology requirement | Training targeted at value-addition are only for show. Farmers are trained in facilities and, when they return home the equipment is not accessible. |
| Cheap power and labor costs | FEMSEDA and INBAR provide skills training to bamboo craftsmen to make more “modern” and advanced furniture with decorations that require higher levels of processing. |
| Lack of value chain approach (no horizontal and vertical integration) | A general lack of policy have resulted in underdevelopment of the bamboo sector. |
| Harmonize with governmental strategic plan of industrialization environment | Recently, the country has developed a national bamboo strategy and action plan. |
| Shortage of hard currency to import machinery and input materials | Perception of bamboo as a poor mans timber and less durable product |
| Government is encouraging investment and providing support in the form of land, loans, and tax exemption | Production of bamboo panel, boards and composite for condominium and modern houses |
| Bamboo in Ethiopia, which is at infancy stage dominated by low priced and by low quality products, is mainly used for construction fence and households as well as agricultural utility products, furniture fuel wood, feed and fodder. | Poor workmanship and lack of technical know how for modern bamboo construction |
| + Ethiopia has one of the largest bamboo sector in Africa. | + Traditional skill sets and culture of using of bamboo in construction |
| - | - Lack of treatment and preservation |
| Majority of construction activities involves use of Eucalyptus tree, non-renewable natural resource, as a scaffolding material. | + Government and agencies focused on developing alternative construction materials |
| + Among the renewable resources, bamboo is quick growing and abundantly available in the country, using it for scaffolding material can be taken as a possible solution to rectify such problem. And ultimately reduce the current pressure on natural forests. | Poor infrastructure network |
| - Bamboo Technology transfer available with in research agencies | + |


Nowadays, organizations like FEMSEDA and INBAR train bamboo craftspeople to make more “modern” and complex furniture with decorations that require more processing. Furthermore, the country has recently developed a national bamboo strategy and action plan to learn about the structural potential of bamboo from South Asian countries’ experiences.

2. **WO strategies**—are intended to improve internal weaknesses by capitalizing on external opportunities

### 5.1.2. Constraints

Even though Ethiopia has a substantial raw material base, its distribution is not uniform across the country. This is a problem in the quest to industrialize the bamboo resource. There is also a scarcity of capital and advanced technology, as well as hard currency for importing machinery and input materials and implementing a value chain strategy (no horizontal and vertical integration).

The country’s low electricity and labor costs, on the other hand, make it easier for the government to align its industrialization strategy. The government encourages investment and aids inland through loans and tax breaks.

3. **ST strategies**—Make use of a company’s strengths to avoid or mitigate the impact of external dangers.

### 5.1.3. Vulnerabilities

Bamboo is widely regarded as a poor man’s timber and a less durable product due to a lack of infrastructure and treatment and preservation centers. This has harmed artistic quality and resulted in a scarcity of technical know-how for modern bamboo construction.

Traditional skill sets and culture of using bamboo in construction, as well as technological transfer available through research organizations, relieve the government and agencies of the burden of producing alternative construction materials. As a result, bamboo panels, boards, and composites for modern homes are produced.

4. **WT strategies**—are defensive strategies aimed at eliminating internal flaws and avoiding external threats.

### 5.1.4. PROBLEMS

Despite the presence of a vast bamboo population in Ethiopia, most building activities utilize the usage of Eucalyptus trees, a non-renewable natural resource, as scaffolding material. In this light, bamboo, which grows quickly and is abundant in the country, can alleviate the existing burden on natural forests. Using bamboo as an alternative material for much more than construction fences and houses and agricultural utility products, furniture, fuelwood, feed, and fodder might be considered a feasible solution to such a problem.

### 5.2. Result validation

As a way of triangulation, document analysis is frequently used in conjunction with other qualitative research approaches. To reduce bias and establish credibility, documentary evidence is mixed with data from interviews. Aside from the documents, the qualitative researcher is expected to draw on numerous (at least two) sources of evidence. This seeks convergence to generate a “confluence of evidence that breeds credibility,” reducing the impact of potential biases that may occur in a single study. As a result, the researcher must protect against the charge that the conclusions of a survey are simply an artifact of a single source (investigator should guard against over-reliance on documents). As a result, standardized questionnaires are employed in conjunction
with document inspection. It is designed to include strategic action plans that must be implemented to reach an acceptable solution. The validation process identifies four action focuses (figure 8).

- Things that MUST be addressed immediately: Research and support
- Things that can be handled now: Facility for bamboo construction
- Things that should be researched further: Institutionalizing bamboo construction
- Things that should be planned for the future: Bamboo resource management

5.3. Expert method

5.3.1. Demography
It was vital to evaluate the competence of experts in education and research and their familiarity with the study process. As a result, standards for assessing expert competency are required. A survey of 7 potential experts was conducted to examine the competence of experts and their relevance to the aims and objectives of the expert opinion approach (Figures 9, 10, and 11).
5.3.2. Selection of experts

The pool of specialists is made up of bamboo researchers as well as building professionals. The contributors have extensive experience with bamboo material, ranging from study project detailing to normal development. According to their response, the slow pace of bamboo acceptance and a lack of guiding principles have contributed to the scarcity of experts in the field.

Experts were asked to describe their study on the creation of alternative building materials based on bamboo. Respondents cover a wide range of study subjects relating to bamboo material. Two areas of concentration were an experimental exploration of bamboo as a structural material and alternative material for reinforcement, while sustainable bamboo construction and structural grading also played a role. Furthermore, managerial jobs and applied research with practical expertise were emphasized. In terms of their amount of involvement in the study under consideration, the experts were unequivocal. There were idea blocks related to the current investigation. For example, getting a low-cost alternative building material, renewable, environmental, and available material, bamboo materials mechanics and characterization, and processing techniques were some of the topics raised to demonstrate the researcher’s alignment with the research.

Opinions were obtained from specialists who have worked with well-known organizations such as National Bamboo Construction Center (NBCC), International Bamboo and Ratten organization (INBAR), Federal Micro and Small Enterprises Development Agency (FeMSEDA), Ethiopian standards agency, Ethiopian Institute of Architecture, Building Construction, and City Development (EiABC) and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). Participation in subject research, leadership at a bamboo-based construction unit, training and standard Preparation, and other activities all contributed to the formation of the association.
5.3.3. Consensus of experts on bamboo formwork

One of the difficulties in installing bamboo formwork is the lack of complementary joinery methods. Most experts (85.5%) believe that these have an automatic influence on joint tightness. The need for skilled workers and the difficulty in obtaining the correct dimension are additional factors to consider. This makes perfect sense because there is no uniform norm to which laborers can become accustomed (Figure 12, 13).

In terms of technical specifications, bamboo material falls short of the mark. Almost unanimously, specialists agree that bamboo material is challenged in achieving the minimum parameters of conventional formwork. As a result, the ability of bamboo formwork to shape and support the fluid concrete until it dries, to sustain the intended loads and any additional applied loads during construction, to form a tight fit between planks or make gaps and prevent bulging, and to tolerate distortion is called into doubt (figure 14).
On the bright side, all respondents gave a 100% remark about how a bamboo-made formwork satisfies an economic requirement. Even if the price of assembly and erection is thought to be high by 57.1% of the researchers (with even distribution of transportation and replacement of bamboo culm, 14.3% each), the low-cost material, energy, and labor requirement is a positive attribute towards the adoption of bamboo material. And the ease of handling either by hand or mechanical means is a bonus (Figure 15, 16 and 17).

5.4. Scoring model for suitability of scaffolding
The total score for a specific set of characteristics is the sum of each group's weighted scores for a specified item. This should then be multiplied by the weighted average of each distinctive group. The weighted score for each package versus the three primary features analyzed is obtained when all of this is added. This is then multiplied by the criterion's weight, and the aggregate yields the relative weighted score for each sub characteristic set. Table 4 below demonstrates the full numeric data for the identification of the significant factors.
| Safety | Scores | Sub Characteristics 1 (%) | Sub Characteristics 2 (%) | Sub Characteristics 3 (%) | Sub Characteristics 4 (%) | Sub Characteristics 5 (%) | Sub Characteristics 6 (%) | Sub Characteristics 7 (%) |
|--------|--------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|
|        | -100   | 14.30                     | 16.70                     | 14.30                     | 28.60                     | 0.00                      | 0.00                      | 0.00                      |
|        | -50    | 42.90                     | 66.60                     | 14.30                     | 28.60                     | 43.90                     | 33.30                     | 42.90                     |
|        | 0      | 14.30                     | 0.00                      | 28.60                     | 0.00                      | 33.30                     | 14.20                     | 0.00                      |
|        | 50     | 28.50                     | 16.70                     | 28.50                     | 14.20                     | 57.10                     | 16.70                     | 42.90                     |
|        | 100    | 0.00                      | 0.00                      | 14.30                     | 28.60                     | 0.00                      | 16.70                     | 0.00                      |
|        | Sum    | 100.00%                   | 100.00%                   | 100.00%                   | 100.00%                   | 100.00%                   | 100.00%                   | 100.00%                   |
|        | Weighted | -21.5                     | -41.65                     | 7.1                       | -7.2                      | 7.1                       | 8.4                       | 0                         |

| Operation and application | Scores | Sub Characteristics 1 (%) | Sub Characteristics 2 (%) | Sub Characteristics 3 (%) | Sub Characteristics 4 (%) | Sub Characteristics 5 (%) | Sub Characteristics 6 (%) | Sub Characteristics 7 (%) | Sub Characteristics 8 (%) |
|---------------------------|--------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|
|                           | -100   | 0.00                      | 14.30                     | 16.70                     | 14.20                     | 33.30                     | 0.00                      | 0.00                      | 0.00                      |
|                           | -50    | 57.10                     | 42.90                     | 33.30                     | 28.60                     | 0.00                      | 0.00                      | 0.00                      | 0.00                      |
|                           | 0      | 0.00                      | 33.30                     | 28.60                     | 16.70                     | 0.00                      | 14.30                     | 14.30                     | 14.30                     |
|                           | 50     | 28.60                     | 14.30                     | 16.70                     | 28.60                     | 33.30                     | 57.10                     | 0.00                      | 0.00                      |
|                           | 100    | 14.30                     | 28.60                     | 0.00                      | 0.00                      | 16.70                     | 42.30                     | 85.70                     | 85.70                     |
|                           | Sum    | 100.00%                   | 100.00%                   | 100.00%                   | 100.00%                   | 100.00%                   | 100.00%                   | 100.00%                   | 100.00%                   |
|                           | Weighted | 0.05                      | -3.55                     | -25                       | -14.2                     | 0.05                      | 71.45                     | 28.55                     | 85.7                      |

| Time | Scores | Sub Characteristics 1 (%) | Sub Characteristics 2 (%) | Sub Characteristics 3 (%) | Sub Characteristics 4 (%) |
|------|--------|---------------------------|---------------------------|---------------------------|---------------------------|
|      | -100   | 14.30                     | 0.00                      | 57.10                     | 16.70                     |
|      | -50    | 57.10                     | 28.60                     | 14.30                     | 16.70                     |
|      | 0      | 0.00                      | 0.00                      | 0.00                      | 0.00                      | (Continued)
|       | Sub Characteristics 1 (%) | Sub Characteristics 2 (%) |
|-------|---------------------------|---------------------------|
| 50    | 28.60                     | 28.60                     |
| 100   | 42.90                     | 0.00                      |
| Sum   | 100.00%                   | 100.00%                   |
| Weighted | -28.55                  | -49.95                   |

**Cost**

| Scores | Sub Characteristics 1 (%) | Sub Characteristics 2 (%) |
|--------|---------------------------|---------------------------|
| -100   | 0.00                      | 28.60                     |
| -50    | 14.20                     | 71.40                     |
| 0      | 0.00                      | 0.00                      |
| 50     | 42.90                     | 0.00                      |
| 100    | 42.90                     | 0.00                      |
| Sum    | 100.00%                   | 100.00%                   |
| Weighted | 57.25                  | -64.3                    |
Table 5. Safety criteria significance level analysis

| Sub Characteristics | Magnitude | Significance Level |
|---------------------|-----------|--------------------|
| 2                   | −43.10    | 17.16              |
| 1                   | −28.40    | 31.23              |
| 5                   | 8.47      | 34.83              |
| 7                   | 3.62      | 38.54              |
| 3                   | 12.56     | 72.21              |
| 6                   | 36.36     | 77.88              |
| 4                   | 10.48     | 78.16              |

As a result, the sub-characteristics used to assess bamboo’s viability as a scaffolding material are presented in the order of their impact on the ease of adoption. The components with the greatest negative magnitude and the lowest significance level indicate a point that should be carefully considered before employing bamboo as a scaffolding material. On the contrary, the highest-valued sub-characteristics are seen as a beneficial tool in using bamboo material.

5.5. Safety
The analysis revealed that the most significant characteristic is that the maximum bending strength of bamboo scaffolds can be guaranteed by special consideration of bamboo variable material strength and the moisture content in the material.

The safety aspect is self-explanatory, and the authors believe that factorial analysis of the components has indicated that special consideration should be given in scaffolding construction of varying loads when utilizing a highly variable natural culm. Explaining the material’s inherent material behavior and considering filling such fluctuation of strength down the length of the bamboo culm could justify user trust. According to experts, the varying strength of bamboo material, as well as the effect of moisture content in it, play a role in bending resistance for buckling. The strength variety, of course, is what gives this trait its dominance. Besides, developing a mechanism to increase bending strength or reduce the buckling effect of bamboo would be the next level of research, as would bracing, connecting, and supporting the scaffolds’ ends, and this would be an interesting subject of research requiring experiments and structural computational studies. This paper suggests that such issues shall be considered in future research on Ethiopian indigenous bamboos. Treatment of bamboo is recommended, but not for the primary benefit of increasing strength, as this depends on the amount and type of sustained loads, as well as the level of durability.

The significant variability in bamboo strength should be appropriately considered when designing and preparing the scaffolding material, and depending on the type of bamboo species, more energy, methods, and cost may be incurred as a result of this issue. This implies that one of the most important factors to consider when designing bamboo scaffolding is safety. In the case of Ethiopian bamboo, for example, the strength variability of a culm would be considered technically by modifying the spacing between scaffolds, and alternative sizes of bamboo culm would also be considered as part of a solution in how to minimize such strength variability. A study is being conducted to address the issue of variability in bamboo species when used for scaffolding in the future. The significance level and related sub-characteristics are shown in Table 5 below.

5.6. Operation and application
The data shows that a sub-characteristic of higher wastage of bamboo scaffolding in sharp and uneven places significantly impacted the operation and application of bamboo. Recycling bamboo
may be recovered from its usage as scaffold material into useful intermediate raw material; on the other hand, it was discovered to be the least factor influencing operation and application. Table 6 below demonstrates the full scoring model.

### 5.7. Time

According to the data analytics as shown in Table 7 below, the factor Preparation before the start of work is not required for bamboo scaffolding was discovered to be the most influential factor for the criterion time; on the contrary, the factor The least significant factor is that frequent inspections are required to maintain the structural integrity of the bamboo scaffolds after the scaffolding system is installed.

**Cost**

The factor maintenance expenses of bamboo scaffolds are expensive is a key significant component for the criteria cost, while the bamboo scaffold is the most affordable being the least influencing factor as shown in Table 8.

And the following conceptual map (figure 18) can be used to understand and principles behind each factor.
6. Conclusion and future remark

Based on a pre-defined criterion, several locally produced documents were identified and included in the initial instance of the research. These documents provide an overview of the current state of the bamboo construction industry. Following that, four priority areas for SWOT analysis were identified: value chain and market evaluation, investment incentives and value addition, bamboo in construction
and research support, and timber substitution and resource management. A SWOT matrix was created to avoid a long list of factors. This provided a general understanding of where the industry is right now. For the final phase of the quantitative analysis, a scoring model was utilized to calculate the weight of expert comments on the suitability of bamboo as a scaffolding and formwork material.

To assess the suitability of bamboo as a scaffolding material, four criteria were chosen: safety, operation and application, time, and cost. The overall score was calculated using a weighted sum. The sub-characteristics used to evaluate bamboo's viability as a scaffolding material were listed in the order of their impact on adoption ease. When used as a scaffolding material, the non-uniform strength of bamboo was discovered to be a significant disadvantage in terms of safety. One source of concern was an increase in bamboo scaffolding waste insensitive and uneven areas. Bamboo scaffolding has time and cost advantages, with a shorter lead time before construction begins and an economic benefit, respectively.

According to experts, one of the challenges in installing bamboo formwork is a lack of complementary joinery methods. Furthermore, experts believe that bamboo material falls short of technological requirements. On the plus side, every single respondent stated unequivocally that bamboo-made formwork meets a low-cost requirement.

It is critical to creating strategic action plans that include the use of bamboo as a temporary material. Four action focuses were chosen as a result of the analysis.

7. Things that MUST be addressed immediately: Research and support
   • It is necessary to investigate the use of bamboo in composite systems with other existing building materials, such as wood or steel components.
   • Promote the establishment of new bamboo plantations. Encourage large and small-scale bamboo plantations by providing necessary technical assistance and training.
   • Incorporating bamboo development and management into the school curriculum.
   • Providing technical experts, farmers, and other development practitioners with short-term training workshops to improve and expand their knowledge of using bamboo as a temporary material.
   • To ensure long-term supply, improve vertical integration among growers, primary processors, businesses, and sectors.
   • Increase public awareness and sensitization to encourage greater use of bamboo scaffolding and formwork, as well as access to information for bamboo material marketing.
   • Coordination of disaster-resistant construction technology transfer and capacity building for local carpenters, masons, and line department officials (foundation, walls, truss, joinery.)

8. Things that can be handled now: Facility for bamboo construction
   • Create and connect a centrally located common preservation and treatment unit for bamboo construction, allowing for the availability of treated bamboo poles for building.
   • Efforts are being focused on critical areas such as preservation and effective connectivity mechanisms.
• Create a national policy, strategy, and action plan that ties important sectors together with national goals and objectives.
• Cross-industry integration of bamboo with other industries such as construction, energy, and lumber to facilitate temporary material creation or market demand
• Each cluster improves a model production and training center by providing primary processing, preservation, and treatment facilities.
• Adoption of advanced bamboo technology and innovation To address specific gaps and issues, subsector countries and strong local research support are required.
• Integrating bamboo application systems into the educational system to ensure a consistent supply of well-trained human resources
• A knowledge management system that is retrievable, accessible, and user-friendly and allows for the sharing of available knowledge.
• Practical demonstrations, as well as research and development, aim to persuade others.
• Knowledge of indigenous bamboo propagation, management, and application aids in the development and ongoing research.
• Develop connectivity and allow bamboo poles in wood depots, as with eucalyptus.
• Make contact with the Ministry of Construction and learn about new advancements in bamboo scaffolding and formwork.
• Provide policy and institutional support to encourage the marketing of bamboo scaffolding and formwork.
• Encourage the development of new bamboo industries and the expansion of existing ones.

9. Things that should be researched further: Institutionalizing bamboo construction
• Other structural components will be subjected to additional bamboo testing and characterization.

• Defining bamboo in the organizational structure and creating enabling institutions, as well as building human capital and bridging the skills gap
• Create relevant bamboo units and a pool of experts at the federal, regional, and woreda levels.
• Various incentive packages are being offered to persuade the private sector to use bamboo as a structural material.
• Establishment of a certification system for bamboo production and processing.
• Create standards and certification systems for bamboo construction to facilitate financing, loans, and the receipt of construction permits.
• Target construction market development by demonstrating the use of structures in strategic locations to instill trust.
• There is a well-established market for bamboo items, as well as a favorable environment for artists and manufacturers to innovate and improve bamboo materials.

10. Things that should be planned for the future: Bamboo resource management
• Bamboo resource inventories are taken regularly to ensure the long-term management of bamboo forest resources.

• Create micro-businesses that process bamboo and use it for scaffolding/formwork.
• Bamboo resource inventories are taken regularly to ensure the long-term management of bamboo forest resources.
Author statement
The authors are currently lecturers at Addis Ababa’s Ethiopian Institute of Architecture, Building Construction, and City Development. Their research interests include the use of bamboo as a sustainable building material, alternative construction materials and technologies for affordable housing, and leveraging innovation and emerging technologies through building information modeling (BIM).

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Author details
Ermias A. Amede
E-mail: ermias@gmail.com
ORCID ID: http://orcid.org/0000-0002-9671-5814

Leule M. Hailemariam

Denamo A. Nuramo
1 Chair of Appropriate Building Technology, Ethiopian Institute of Architecture, Building Construction and City Development, Addis Ababa University, Addis Ababa, Ethiopia.

2 Chair of Construction Materials and Engineering Design, Ethiopian Institute of Architecture, Building Construction and City Development, Addis Ababa University, Addis Ababa, Ethiopia.

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