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Investigation of Traditional Bamboo House Construction Practice and the Need for bamboo Construction Technology in Awi Zone

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BAHIR DAR UNIVERSITY
BAHIR DAR INSTITUTE OF TECHNOLOGY
SCHOOL OF RESEARCH AND GRADUATE STUDIES
FACULTY OF CIVIL AND WATER RESOURCE ENGINEERING

MSc Thesis

**Investigation of Traditional Bamboo House Construction Practice and the
Need for bamboo Construction Technology in Awi Zone**

By

Asimie Agegnehu

March 15, 2021

Bahir Dar, Ethiopia



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Need for bamboo Construction Technology in Awi Zone**

By

Asimie Agegnehu

Main advisor: - Kassahun Admassu (PhD)

Co-advisor:- Mrs. Bethlehem Telahun (MSc)

A Thesis Submitted to School of Graduate Studies in Partial Fulfillment of the Requirements for
the Degree of Master of Science in Civil Engineering (Construction Technology and
Management Engineering)

March 15, 2021

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FACULTY OF CIVIL AND WATER RESOURCE ENGINEERING

I hereby confirm that the changes required by the examiners have been carried out and incorporated in the final thesis.

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Investigation of Traditional Bamboo House Construction Practice and the Need for Bamboo House Construction Technology in Awi Zone

Declaration

This is to certify that the thesis entitled "Investigation of Traditional Bamboo House Construction Practice and the Need for bamboo Construction Technology in Awi Zone" submitted in partial fulfillment of the requirements for the degree of Master of Science in (Construction Technology and Management Engineering) under Faculty of Civil and water Resources Engineering, Bahir Dar Institute of Technology, is a record of original work carried out by me and has never been submitted to this or any other institution to get any other degree or certificates. The assistance and help I received during the course of this investigation have been duly acknowledged.

Asimie Agegnehu



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Date

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List of Abbreviations

BARADEP	Bamboo and Rattan Development Programme
BHD	Breast Height Diameter
INBAR	International Network for Bamboo and Rattan
MoARD	Ministry of Agriculture and Rural Development
MoTI	Ministry of Trade and Industry
MSMEs	Micro-, small- and medium-scale enterprises
NGOs	Non-Governmental Organizations
OSB	Oriented Strand Board
SPSS	Statistical Package for Social Sciences
TT	Technology Transfer
UNIDO	United Nations Industrial Development Organization
USD	United States Dollar

Abstract

Bamboo for housing construction is a paramount material due to its adaptability characteristics, cost advantage, wider accessibility and environmental friendliness. Bamboo housing in Injebara was in practice sustained with traditional skills and techniques by the local farmers, for so long. This study focused on bamboo technology for bamboo housing construction in Awi Zone of Ethiopia and it has also identified the current use of bamboo for construction, challenges facing bamboo improvement, factors influencing bamboo application and to propose the mechanism of technology transfer in bamboo house construction technology transfer in the bamboo house construction future. The main tools for the collection of data were questionnaires, interviews and case studies which were used to identify the various challenges and factors influencing bamboo construction technology. The data were analyzed using a Statistical Package for Social Sciences software within its mean value. The findings of this study indicate that lack of research funds for bamboo building materials with a mean of 4.22; inadequate technologies and weak technology transfer in bamboo construction with a mean of 4.13 and lack of finance to facilitate bamboo construction technology with a mean of 4.11 are the major problems of bamboo construction technology development. As a means of mitigating the challenges technology transfer mechanism in bamboo house construction technology is proposed to address the challenges of bamboo improvement, factors of application and implementation of bamboo house construction in an improvised way.

Keywords: Appropriate technology, Awi, Bamboo, Construction, Housing, Product, Traditional, Technology transfer

CHAPTER ONE

INTRODUCTION

1.1. Background of the Study

Bamboo is one of the oldest and most flexible building materials with many uses in the field of construction, particularly in developing countries. It is strong and lightweight and can often be used without processing or finishing. Bamboo constructions are easy to build, resilient to wind and even earthquake forces, and readily repairable in the event of damage [1].

It is a current construction material among rural societies in Ethiopia, especially in regions of Awi; where it grows naturally. The country is rich in traditional bamboo housing designs, practices and skills. However, the sustainability of the traditional and modern architecture used by the poor communities in Ethiopia is under threat due to reducing resource availability, increasing rural populations, and a shortage of contemporary processing technologies. Financial and economic analysis carry out throughout the study also found that, by using bamboo for tourist lodges or cost efficient housing in urban areas. The government is also willing to develop bamboo as another construction material using laminated bamboo and is planning to establish a manufacturing industry. This will provide a possible road for incorporating bamboo into the formal housing industry [2].

Bamboo is commonly used in many forms of construction, mainly in rural housing. These buildings are frequently simple and constructed based on a living ritual of local skills and methods. Technology improvement and creativities affianced up by the essential and state government has enabled in the growth of bamboo in construction and structural uses. Different technologies on jointing, protection and protection of bamboo has been technologically advanced which has better its durability, quality and opened new areas for bamboo as a wood substitute. The traditional bamboo used in rural housing can currently be transformed into new and progressive bamboo based products with the most contemporary technology and can be used in best rating houses in roofing, flooring, doors, windows, etc. The bamboo area has been getting provision from several participants that consist of the administration, private, research and

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financial institutes. These participants are ratifying and amending the use of bamboo for construction[1].

The benefits of technology transfer (TT) in bamboo products can be realized by (1) improving product and service quality as well as decreasing price, which ultimately results in greater domestic and international competitiveness; (2) modification into new products or markets, which results in extended business activity; and (3) ‘learning by doing’ outcomes from co-operation with technologically-advanced foreign firms [3].

1.2. Statement of the Problem

Currently in Ethiopia, the construction industry is growing due to the launch of major infrastructure projects together with many public buildings, commercial buildings and housing development programs. However, bamboo technology is becoming Ethiopia, especially in the bamboo construction sector in Awi Zone due to an insignificant consideration given to such a subject. Bamboo construction technologies were not organized efficiently in the construction industry, because of the deficiency of appropriate technologies, modern tools and skilled professionals specialized in the bamboo sector. Bamboo production and utilization techniques in Ethiopia are still quite traditional; it is used by farmers in numerous areas of the country. Most houses are usually built by poor farmers who assemble the material from their farms and the wild. This has led to bamboo being deliberated as a poor construction material in the rural communities and therefore technologies are crucial issue to modernize the industry of bamboo house construction.

In Ethiopia, bamboo as a construction material was not completely utilized in the construction industry and this shows that the bamboo housing construction technology still remains at its infant stage. Since bamboo is readily available and less costly unlike cement, sand and steel. The people in focus do need an alternative material and technology. Bamboo is highly renewable and the fastest growing material and has properties that make it suitable for construction as happened to be elsewhere.

The challenges existing for technology transfer in bamboo construction like; unwillingness of the transfer of the real technology and technical know-how, has led to unproductive technology ownership, incorrect technology selection, unmatched with the current practice elsewhere,

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shortage of practical training and too much rush in the adoption process. Therefore, this research attempts to fill these gaps by investigate traditional bamboo house construction practice and bamboo house construction technology in Awi Zone.

1.3. Objectives

1. 3.1. General objective

The general objective of this study is to investigate traditional bamboo house construction practice and the need for bamboo house construction technology in Awi Zone.

1.3.2. Specific objectives

- i. To identify the challenges of bamboo improvement in housing construction sector.
- ii. To investigate the major factors affecting bamboo application for construction.
- iii. To identify the governing factors of technology transfer in bamboo house construction.
- iv. To propose technology transfer mechanism in bamboo house construction technology.

1.4. Research Questions

1. What are the existing challenges of bamboo improvement in construction?
2. What are the major factors affecting bamboo application in the construction sector?
3. What are the governing factors of technology transfer in bamboo house construction and
4. How to propose the mechanism of technology transfer in bamboo house construction technology?

1.5. Significance of the Study

The study helps to analyze and promote a better understanding of bamboo construction technology transfer in the construction sector. Adopting technology helps in increasing productivity, increasing job opportunity, minimizing cost, effective time use and improved quality in bamboo use for construction. Also it provides information on how bamboo construction technology could offer some practical ideas, based on real construction practices in the development of bamboo construction technology for those who badly need a decent shelter.

1.6. Scope of the Study

This study is limited on bamboo construction technology in the Awi Zone of Ethiopia. The study has focused on the bamboo housing construction practice and the way of modern bamboo construction technology based on questioners, interview case study and observation.

1.7. Limitation of the Study

The limitations of this study are the respondents who had reservations to answer questionnaires and interviews. Bamboo materials management and bamboo building policy is not effectively implemented to use bamboo as an input in Ethiopian construction industry.

1.8. Possible Beneficiaries of the Achievement

1. The traditional house builders who are used to bamboo house construction.
2. Construction stakeholders who work in the bamboo construction sector.
3. Educational institutions, to use the information for academic purposes and further researches.
4. Government policy makers and private enterprises who wish to involve in rural housing development by embracing bamboo technology.

1.9. Organization of the Study

The Organization of the study is divided into different chapters, as follows.

Chapter 1. Background of the study: This section provides the background of the study. The main idea of this chapter is to describe the background of the problem, the objectives and the contribution that could be brought about by the study.

Chapter 2. Literature Review: The chapters provide information on the main subjects of the thesis; the challenges and factors of bamboo construction in the housing construction sector and derive practical suggestions and recommendations to upgrade the knowledge of bamboo construction technology in Awi Zone, Ethiopia.

Chapter 3. Methodology: The chapter provides the plan of the research. In other words, this section explains the research approaches, strategies and data collection methods, and compilation and interpretation techniques.

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Chapter 4. Results and Discussion: It provides the results from questionnaires, interviews and case studies through analysis and discussion of results in contrast with facts in reviewed literatures. The chapter also provides information on the ways of data analyzed method based on ranks of its mean values.

Chapter 5. Conclusion and Recommendation: The chapter summarizes the findings of the research and also forwards recommendation and suggestion for future studies.

CHAPTER TWO

LITERATURE REVIEW

2.1. Bamboo Resources in Ethiopia

There are 70 genera and 1200 species of bamboo in the world which are commonly spread between 46° N and 47° S in the tropical, subtropical and temperate regions of most continents except Europe. Geographically, bamboo distribution can be classified into three Zones: the Asian Pacific Zone, the American Zone and the African Zone. Africa holds about 40 species on over 1.5 million ha of land and two of these species are found in Ethiopia. Though there are different estimates on natural bamboo coverage of Ethiopia over one million ha, which is about 67% of the African bamboo forest cover and 7% of the world's total. The species are under estimation in different parts of the country including specific localities known as Assosa, Injibara, Hagere-Selam, Debre-Zeit and Wondo-Genet. Ministry of Agriculture and Rural Development (MoARD) of Ethiopia through a project called "East African Bamboo Project". [4].

1. The lowland bamboo of Ethiopia (*Oxytenanthera abyssinica*)

It is clearly under the sympodial type. Sympodial type means its underground stem is generally large, thick and short, with dense nodes and many rhizomes, namely the basal part of bamboo culms. Buds bearing on the underground stem grow out of soil, shoot and then develop into bamboo culms. New bamboo culms usually stay close to old bamboo culms, so bamboo culms are densely distributed in clumps [41]. Vernacular names: Mountain bamboo (English), Anini (Agew), Kerkeha (Amharic), Kias (Gamu), Shineto/Shinato (Kefigna), Lemmen/Shimela (Oromigna), Shenbek'wa (Wolayita), lema (Konso, Kembata, Sodo-Gurage, Sidamo), Werye/Shikaro/Shinato (Kefa), and Lewu (Nuwer) is found. *Oxytenanthera abyssinica* Common name and Vernacular Names: savana bamboo/bamboo/plains bamboo (English), Bambou (French), bambu (Italian), shimel (Amharic), betre (Sodogurage), arkay (Tigre, Amharic) and tamia (Welayta). *Oxytenanthera abyssinica* grows in dense clumps usually on dry rocky hillsides in semi-humid lowland savanna, thicket savanna, and dominant in lowland bamboo thickets, at altitudes of 500 to 1300 m asl; it is solid-stemmed bamboo with thick-walled stem. *O. abyssinica* is deciduous, bright green in colour and it has zigzag culms and no thorn [4].



Figure 2. 1: Basic forms of the subterranean Sympodial bamboo (*Oxytenanthera abyssinica*) in Ethiopia[4]

2. Highland bamboo is a monopodial/leptomorphic rhizome bamboo of Ethiopia

Monopodial type :the lathy underground stem grows horizontally under the ground, and is therefore called bamboo rhizome, on each node of which there is one bud arraying in turns. Some buds turn into new bamboo rhizomes, extending successively and rambling in soil [41]. It is a non-clump-forming (single-steamed) or running bamboo with hollow culms. It is evergreen with a maximum diameter of 12.7 cm and a maximum height of 16.76 m [5].



Figure 2. 2: Basic forms of the subterranean parts of monopodia bamboo (*Yushania alpine*) in Ethiopia [5]

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Most bamboo stands in Kosober, north-west Ethiopia, have dark green colour whereas about 40% are yellow-striped (my personal observation). Colour variation is also recognized by the local craftsmen who use the stem for making local furniture and house materials. Still in Kosober area, there is a small-sized bamboo variety that is still not recognized well. Hence, further investigation is needed to ascertain whether there is another species, or whether it is a variety of highland bamboo, or whether it is an extended stem exposure to light that makes the stem of the highland bamboo turn into orange yellow colour [4].

2.2. The Use of Bamboo in the Construction Sector

The excessive production capacities of bamboo add to its easy cultivation, producing, harvesting, transporting and handling makes the bamboo an exciting material for the construction sector. Its early use and popular character make it present in most constructive values of the world, especially in Eastern countries such as Indonesia, India, China and Japan. In the Americas, during the discovery period, Spanish labeled the presence of vast forests of giant bamboo. Most of these forests were then distributed over southern Mexico, Central America, South America and northern Argentina, indicating the existence of settlements exploring the use of bamboo in all its vastness. The set of explanations indicates the regions of Central America, Colombia and Ecuador as the regions where bamboo culture in construction is still manifested in America, making them currently reference countries in bamboo technology [25].

Bamboo in the construction sector is used to make all the constituents of building both structural and non-structural. Traditionally bamboo culms were used for assembling housing in a rural community, scaffolding and for building foot bridges. It was used in different ways for roof structure, for doors and windows, walling, ceiling; man-hole covers etc. Traditional uses of bamboos like:- bamboo house, shade house, construction frame, door and window frames, bridges, Fencing, ladder, scaffolding partition walls etc. and contemporary uses of bamboo such as composites or wood substitutes bamboo mat board, flattened bamboo boards, bamboo jute composites, bamboo flooring, plywood, particleboard, fiber board prefabricated houses [1].

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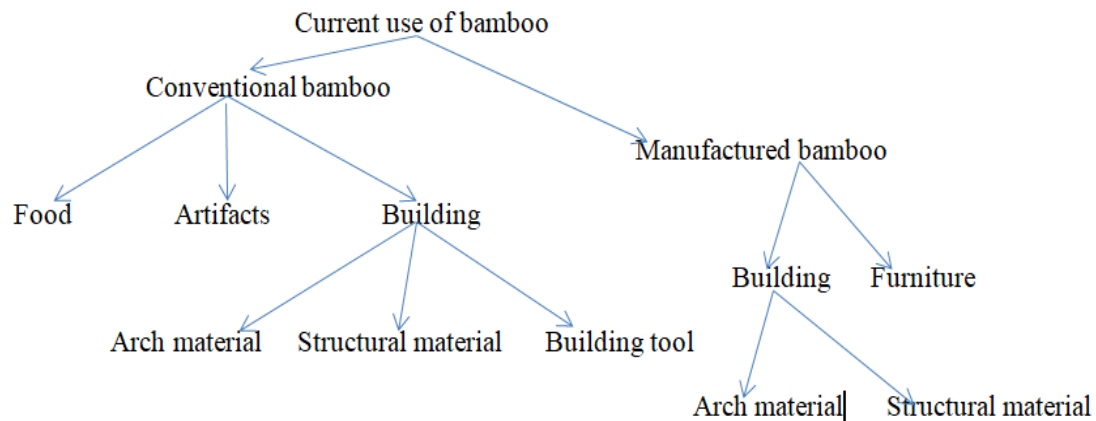


Figure 2. 3 : The hierarchy and relationship of current uses of bamboo products [26]

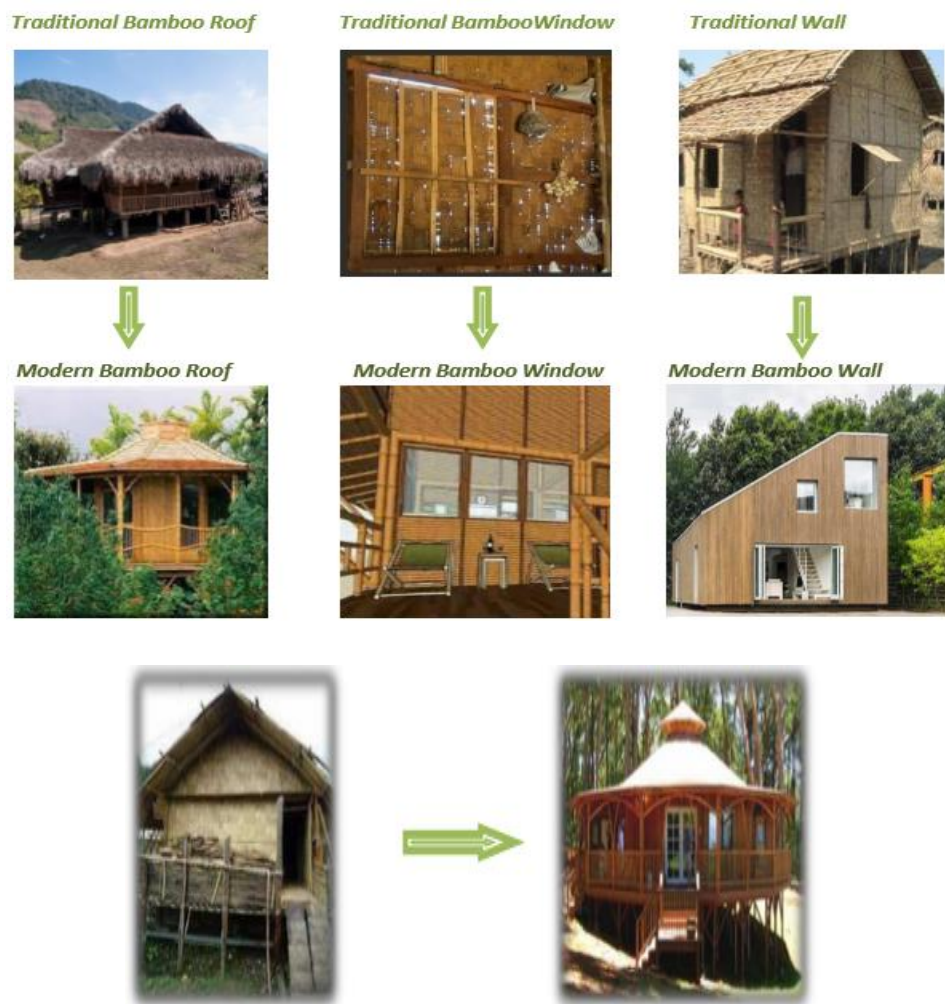


Figure 2. 4: Application of traditional and modern bamboo housing technology [2]

2.3. Bamboo as a Building Material

Bamboo is one of the ancient materials used for the construction of houses and other structures. Bamboo, a native, renewable East African forest resource, could be one alternative source of sustainable building material that can help the region meet its housing needs. Decades of research by bamboo practitioners have confirmed that, when treated and used properly, bamboo is a sound structural and engineering material, which, due to its strength, flexibility and versatility, is a suitable material for use in housing. Recently, the International Network for Bamboo and Rattan (INBAR), the world's only intergovernmental organization dedicated to the sustainable development of bamboo and rattan, and Chinese partners have also confirmed that laminated bamboo can be used in structural applications, presenting new opportunities to standardize bamboo-based construction and produce modern modular housing designs that are potentially suitable for East African markets. Bamboo is very important to Ethiopia, because of the fact that, the country's high forest coverage estimated is only 3.56% which is still alarmingly decreasing, while bamboo can be a substitute for almost all wood products and share this pressure since it is fast growing [6].

Its strength, flexibility and versatility make it appropriate material for addressing every housing constituent when dried and used properly. Bamboo is a versatile, durable, renewable and environmentally friendly material. Bamboo is comparatively cheap, easy to work with and readily accessible in most warm climate countries. It is estimated that beyond one billion people in the world live in bamboo houses and in Bangladesh alone more than 70% of houses are made up of bamboo. Bamboo can be a prospective building material in most of the developing countries where it grows. Fortunately, it grows in most of the African and Asian countries where cheap and sustainable building materials are in high demand. Bamboo is a renewable raw material resource from agro-forestry and if properly dried and industrially processed, constituents made by bamboo can have a reasonable life of 30 to 40 years. Though the natural durability of bamboo differs according to species and the types of treatments, various uses and applications in building construction have recognized bamboo as an environment-friendly, energy-efficient and economical construction material. The bamboo based housing methods has very high potential for mass housing, housing in disaster prone areas and for earthquake resistant structures/houses and other uses. The low quantity of the bamboo based building is an advantage under earthquake condition as compared to masonry structures [7].

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Bamboo's criteria for construction industry [11]:

- ✓ When using bamboo it is worth making sure that it is dried during the drying process, not dry bamboo can lead to kinks and is not focus to use in structures,
- ✓ Bamboo must be neutralized from insects and certain treatment,
- ✓ Bamboo buds can't be used in construction, which can lead to the crushing of the bamboo itself,
- ✓ Before use it is worth proving for the existence of cracks, can lead to kinks,
- ✓ The term of bamboo service can be influenced by on the type, length, wall thickness, and harvesting time.



Figure 2. 5: Dry bamboo culms [11]

2.4. Bamboo housing

According to the work of Vries S. D (2002) amongst humanity's basic needs shelter or housing, ranks fairly high. In literature, it usually follows after water, health, and food. However, housing has been considered as being simply consumptive rather than contributing to a national economy. Bamboo houses are quite common in many countries including China, India, Bangladesh, Indonesia, Philippines, Costa Rica and Ecuador. Over one billion people live in traditional

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bamboo houses. These buildings are usually cheaper than wooden houses (bamboos are among the cheapest building materials), light, strong and earthquake resistant, unlike brick or cement constructions. The favorable characteristics of bamboos make them a suitable material for practically every part of a house (i.e. foundation, flooring, walls and roofs) when treated and used properly. Other key advantages that bamboo construction offers include: easy assembly, prefabrication, simple replacement of structural parts (the bamboo elements can be easily dismantled and reused). New types of prefabricated houses made of engineered bamboo can be packed flat and transported long distances at a reasonable cost. These days especially the low income countries suffer a vast housing problem. Supply is inadequate for the lower income families in particular, and therefore many of them live in houses of inferior quality or even in slums. It has strength, flexibility and versatility and therefore it is a suitable material for practically every part of the house when treated and used properly. The advantages of using bamboo for construction do not end with technical advantages only. It is very economical because it is a local product and therefore amongst the inexpensive building materials. Cultivating bamboo can have very high yields if managed properly. Furthermore, bamboo can be used as a substitute for timber in many applications, and associated to the trees used for that timber, bamboo grows substantially more rapidly. It can contribute to a solution for the deforestation that is at the existent causing concerns for the environment [6].

One major drawback of bamboo is its poor resistance to fungi and bacteria. Without preservative treatment and proper use, the material has a very short life. With the rise of the more durable brick and concrete, bamboo became low-grade to those construction materials and its social status is measured very low. With new technologies of constructing with bamboo, more durable constructions can be attained as well as the better appearance of the house making it more socially acceptable. This is very well worthwhile outlook in mind all the benefits bamboo has as a construction material. Huge development efforts are taking place in Latin America, where different new building systems have been progressive for low-income, middle-income as well as high income households [8].

While reviewing the research of Sharma P.K (2014), the majority of bamboo construction tells to the rural community wishes in developing countries. As such domestic housing predominates and in line with their rural origins, these buildings are frequently simple in design and

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construction depends on a living tradition of local skills and techniques. Other common types of construction embrace farm and school buildings and bridges. Further applications of bamboo related to construction take in its use as scaffolding, water piping and as shuttering and reinforcement for concrete. Most of the present residents of bamboo houses belong to the socially and economically weaker sections in the society due to their poor economic condition. They determine for low cost bamboo houses and hence are of low quality. Thus economic conditions of the residents must be improved to construct quality bamboo houses. Quality bamboos, at low cost must be made available to people who wish to construct bamboo houses. There is a long-standing tradition of bamboo construction, dating back to more than a few hundreds of years. Different cultures have found in this material an economical system of a building, offering sound yet light and easily expendable forms of shelter. The methods, activities and tools are often simple, straightforward, available even to the young and unskilled. Bamboo building construction is characterized by a structural frame approach related to that applied in traditional timber frame design and construction. Bamboo based materials have been used in almost all parts of house construction except for the fireplace and the chimneys. These are defined in detail below [9].

1. Foundation

The use of bamboo for the foundation is rather limited. This is mainly since like timber when in connection with the damp ground, they deteriorate and decay very quickly unless treated with some very effective preservatives. Conversely, despite of their short life, substantial use of bamboos is made as foundation or supporting posts in case of houses built on raised platforms.



Figure 2. 6: Bamboo foundation [9]

2. Flooring

The floors may be at ground level and therefore contains only of compacted earth, with or without a covering of bamboo matting. The preferred solution is to increase the floor above the ground creating a stilt type of construction. This develops comfort and hygiene and can distribute a covered storage area below the floor. The surface of earth floor is sometimes made more stable by paving it with crude bamboo boards prepared by opening and flattening whole culms.



Figure 2. 7: Bamboo flooring [9]

3. Walls

The broadest use of bamboo in construction is for the walls and partitions. The major elements, the posts and beams, generally constitute part or structural framework. They are to carry the self-weight of the building and loads forced by the occupants and the weather. An infill between framing members is required to complete the wall. The purpose of the infill is to protect against rain, wind and animals, to offer privacy and to deliver in plane bracing to ensure the overall stability of the overall structure when subjected to horizontal forces.



Figure 2. 8: Bamboo wall [6]

4. Roofing

The roof offers protection against extremes of weather containing rain, sun and wind, and provides shelter, clear and usable space beneath the canopy. Above all it must be strong enough to fight the considerable forces generated by wind and roof coverings. In this respect, bamboo is ideal as a roofing material- it is strong, resilient and light weighted. The bamboo structure of a roof can comprise of purlins, rafters and trusses.

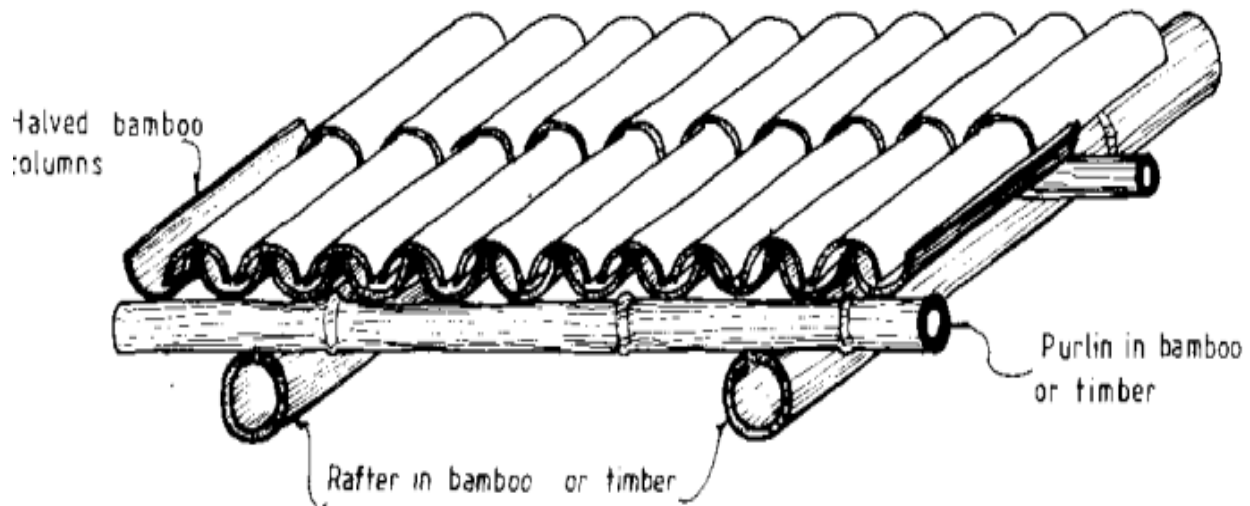


Figure 2. 9: Roof with halved bamboo culms [11]

2.5. Preparation Techniques of Bamboo

The preparation techniques of bamboo are as follows [10].

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1. Durability of bamboo

The outer hard part and the lower part of the culms is more strong than part of the inner wall deteriorating quicker as it is soft. Some features of bamboo are similar to wood, but the features of the microstructure are different. In the same way, the structure of bamboo does not release toxic deposits.

2. Bamboo infection with pests

The high probability of infection of bamboo by pests is due to the presence of starch and other carbohydrates in bamboo. Bamboo must be chemically treated to avoid contamination. This food for pests can destroy the material or make it improper for use.

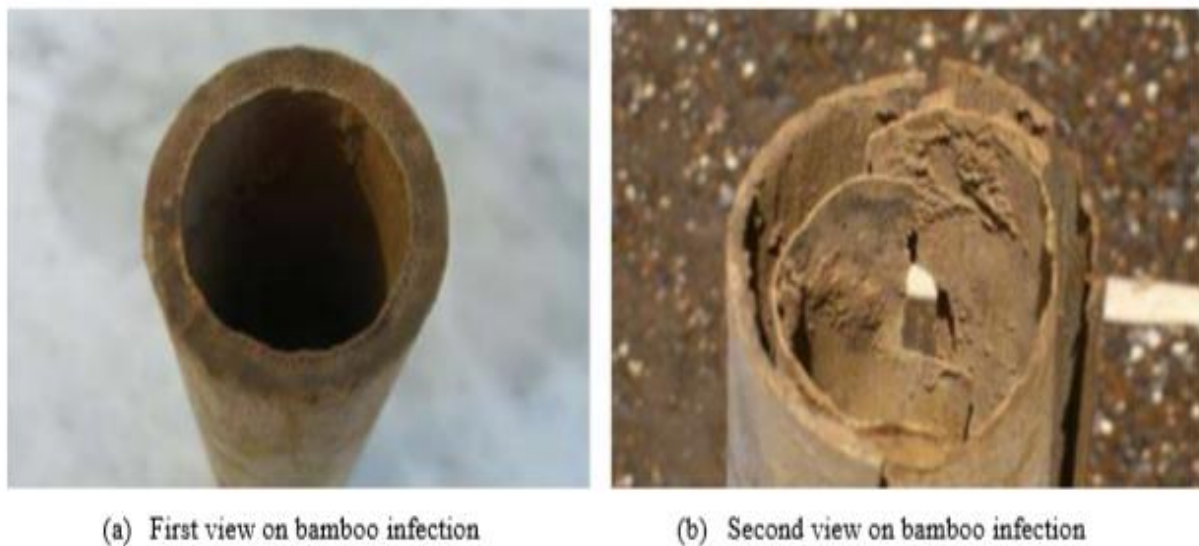


Figure 2. 10: Bamboo infection with pests [11]

3. Leaching bamboo or storing bamboo in water

Bamboo leaching is a traditional method; it is used by native communities and farmers in the Asian and Latin American regions. People quiet use the method of immersing bamboo in water, specifically when bamboo needs to be transported from remote areas. However, single leaching does not warranty long-term fortification but helps to remove starch and increases permeability for future usage by diffusion and pressure treatment. This keeps the bamboo from attack by beetles and parasites.



Figure 2. 11: Immersing bamboo in water [11]

How to store bamboo in water? Bamboo is stored in tanks with water, while adding chemicals. Stages that must be applied necessarily:

- Bamboo knots should be punctured, so water will easily penetrate into the bamboo canes,
- It is necessary to bind the bamboo together or to separate and store them in tanks or in running water,
- Storage of bamboo in the tank. It is necessary to change the water weekly; this will prevent the growth of bacteria that can cause unpleasant odor and discoloration of bamboo,
- It is necessary to use loadings for full immersion of bamboo in water,
- Bamboo should be immersed in water with times, after extraction, it is worth using further chemical treatment. Bamboo should be immersed for at least 3 - 4 weeks
- Bamboo that has been leached for 3 months or more may become stained in the epidermis. This will reduce its physical and mechanical properties.

5. Bamboo treatment with chemicals

The choice of chemicals as protection for bamboo must be selected very carefully, as this can affect the environment. Mostly coatings with borax, a sodium borate mineral, are used. The use of insect ices, such as DDT and PCP, has to avoid as it is ecologically undesirable. These methods preserve the bamboo to be protected against pests. Protection against fungi and decay has to be done by avoiding moisture[11].



Figure 2. 12: Chemical treatment of bamboo [12]

5. Drying bamboo poles

Drying bamboo takes a lot of time because this material easily engrosses moisture; it is called a hygroscopic material. Humidity is 50% - 60%, it can also can be influenced by on the climatic conditions of cutting down and the type of bamboo. During the drying procedure, the diameter of the bamboo can be reduced from 10% to 16%, and the wall thickness from 15% to 17%. The usual and well-known technique of drying bamboo is "drying in the air." After chemical treatment, all bamboo is laid and kept under a canopy or a roof.

Important consideration when drying bamboo [12]:

- First, you must to protect bamboo from direct contact with the ground, escaping humidity, pests and dirt with a fungus.

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- It is necessary to avoid varying humidity. Round poles shouldn't be visible to direct sunlight, for a long time, might form cracks in poles. However, the bamboos, divided into lengths, can be dried in the open sun.
- There should be a circulation of air in a room with bamboo.
- Vertical packing provides the bamboo to dry for a shorter period and is less defeated by a fungal attack. However, it is worthwhile to follow the poles so that there is no curvature or provide a good support system.
- Horizontal lying is commonly used for large batches of bamboo, they are laid on large sheets, and sheets can consist of plastic or glass.
- Every 15 days, bamboo would be turned in the longitudinal way, for even drying.

The technique of air-drying takes from 6 to 12 weeks. This may rely on the humidity of the bamboo and the thickness.

2.6. Advantages and Disadvantages of Bamboo as a Housing Construction Material

2.6.1. Advantages

The various advantages of bamboo are as mentioned below [6]:

1. Tensile strength: Bamboo has higher tensile strength than steel because its fibers run axially.
2. Fire Resistance: Capability of bamboo to resist fire is very high and it can withstand temperature up to 4000 C. This is due to the presence of high value of silicate acid and water.
3. Elasticity: Bamboo is widely preferred in earthquake prone regions due to its elastic features.
4. Weight of bamboo: Bamboos due to their low weight are easily displaced or installed making it very easier for transportation and construction.
5. Unlike other building materials like cement and asbestos, bamboo poses no danger to health.
6. They are cost effective and easy to use.

7. They are especially in great demand in earthquake prone areas.

2.6.2. Disadvantages

Bamboos come with their own set of drawbacks such as [6]:

1. They require preservation
2. Shrinkage: Bamboo shrinks much greater than any other type of timber especially when it loses water.
3. Durability: Bamboo should be sufficiently treated against insect or fungus attack before being utilized for building purposes.
4. Jointing: Despite prevalence of various techniques of jointing, structural reliability of bamboo is questionable.

2.7. Definitions of Technology

Technology is a body of skills, information, and procedures for creating, using, and doing useful things [12]. Technology is the set of corrections, methods, techniques, and supporting mechanisms, which make up the process by which a real product is elaborated [13].

Technology is the yield of technological and organizational capacity, which detentions the way (or ways) in which tangible and intangible resources may be physically changed into midway and finished goods and services. It becomes almost obvious from these wide technology definitions that technology is understood by many as the most significant factor in improving productivity, quality, and competitiveness. The main feature of most definitions is that they indicate one or more specific parts of technology such as its type, technique and subject. Moreover, the various definitions for technology underline its multidimensional characteristics such as flexibility, institutional, organizational, and cumulative nature [14].

2.8. Definition of Technology Transfer

Technology transfer has been defined primarily as the process whereby technology is moved from one physical or geographic location to another for use toward an end product. This transfer can take place either locally from one sector or firm to another or, it can take place across

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national boundaries, from one country to another, which is commonly accepted as international technology transfer [15]. Technology transfer includes the acquisition of "inventive activity" by secondary users. It indicates that technology transfer may not always involve the transfer of machinery or physical equipment. Knowledge can also be transmitted through training and education, which could include training on how to effectively manage technological processes and changes [16]. Transfer of technology is the transmission of know-how to suit local circumstances, effective absorption, and flow both within a country and from one country to another. As such, technology is not just one source of growth and vitality for different enterprises and entire nations, but the essential source in many cases [17].

2.9. Technology Transfer Mechanisms

Technology transfer is one of the best straight and effective ways to encourage economic development by applying innovative technologies. This device consists of transferring or distributing technology from the places of its origin to a wider circulation among more users. There are a lot of technologies industrialized by researchers on the application of bamboo materials, and the effective transfer of these technologies could aid enterprises avoid constant research and stimulate a direct use of these technologies. However, the enterprise has no channels for launching cooperative relations with universities where they assumed mature technologies about bamboo materials were available. Their company had to pass extra time and costs on emerging bamboo processing technologies if they wanted to apply these materials. It can be seen that without technology transfer devices, mature technology has less chance to be applied. This concludes that the absence of a technology transfer mechanism hinders the application of bamboo in the construction industry [18].

2.10. Bamboo strategy and policy in Ethiopia

In view of the current and prospective industrial, socio-economic and environmental significance of bamboo resources, sustainable use rates special attention. Hence, as one vast product, it needs to be either systematically key issue into the existing organizations or some other responsible institution that could take the main and exert a big effort to its development should come into being. Formulation of bamboo development and industrial policies and policy firming international relationship are important points to be exhaustively measured. The establishment of nurseries of introduced bamboo species. This action was the combined effort of the Ministry of

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Agriculture and Rural Development (MoARD) and the Ministry of Trade and Industry (MoTI). Such effort needs to be scaled-up and the number of trainees in both management and processing increased considerably. It was at the beginning of the Ethiopian Millennium (2007 and 2008) that bamboo was declared to be “the Millennium grass”. Such initiatives are crucial. So, policies that bring such efforts into effect are important. Most possibly, entrepreneurs are financially weak and find it difficult to be involved in big commercial production and marketing. Accordingly, there is a need to develop a mechanism that supports them as well. Support is required from government and non-governmental organizations [42].

2.11. The Bamboo Sector in Ethiopia

In 2009, the United Nations Industrial Development Organization (UNIDO) offered the Bamboo Sector Strategy Framework to the government of Ethiopia to strengthen the bamboo sector within five years. The deficiency of an enabling environment and ineffectual governmental and institutional efforts remain the main challenges to the enlargement of the sector. The Ethiopian bamboo sector enlargement is at its infant stage. Recently few industries have on track producing bamboo industrial products. Overall, the bamboo sector delivers low economic return for farmers and other actors along the bamboo value chains [19]. To date, only a few studies have observed into the bamboo sector in Ethiopia. bamboo is an important service, both environmentally and ecologically, for producing regions [20]. The present utilization, marketing, and trade of bamboo products remain under-industrialized, with minimal contribution to the economy. Bamboo value chain development is very important to Ethiopia; because bamboo has a tremendous potential for economic and environmental development and international trade. Bamboo now is using as bamboo raw materials, bamboo charcoal, bamboo housing, bamboo pulp, paper and cloth, bamboo panels, bamboo weaving products and crafts, bamboo fuel, bamboo shoots for food purpose, bamboo furniture. Bamboo is an abundant resource in Ethiopia and has a great potential for commercialization, which can drive rural development. It is restricted to the construction of houses[21]. The recent market and demand in Ethiopia for hand-made bamboo products is insignificant, and few existing enterprises specialize in processing bamboo furniture with higher value [22].

There is a big prospective for the bamboo market to grow further. These are reasons for innovations and developments in the utilization and marketing opportunities of bamboo in

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Ethiopia. There have been efforts within the last couple of decades to improve the bamboo sector by numerous international organizations, non-governmental organizations (NGOs), and the government of Ethiopia. Despite these efforts, the performance of the bamboo market remains undeveloped and limited. Slight has changed for farmers and communities whose livelihoods depend on bamboo. Due to the natural features and the possibilities for high-value-added production of bamboo, smallholder farmers and producers in Ethiopia can greatly benefit from developed utilization and marketing of bamboo. However, the current marketing structure of the bamboo sector is informal and there are no connections, coordination, and integration among the product markets and sources at both the local level and at central markets; farther, the participation of actors in the bamboo value chain remains at a low level of knowledge and skills, with little value addition [23].

2.12. Construction and Structural Application of Bamboo

Traditionally, bamboo culms were used as major building materials for constructing houses or bamboo frame was plastered with cement or clay which has now shifted to the construction of prefabricated bamboo housing. In modern times, engineered bamboo is used to create prefabricated bamboo houses with the help of bamboo based panels, veneers, and laminated boards. A lot of development has taken place to improve the technology and techniques that can be used to create bamboo suitable for construction. There has been an improvement in the preservation and protection technology of bamboo as well as in jointing methods so that the use of bamboo can be proliferated as a construction material. Bamboo can be transformed to create products like bamboo veneers, bamboo panels, corrugated bamboo roofing sheets, bamboo particle board, etc. which can be used as a construction material in different applications. A lots of organizations like Indian Plywood Industry Research and Training Institute, Technology Information Forecasting and Assessment Council, Building Material and Technology Promotion Council etc. are coming up with latest, innovative, cost effective and ecofriendly bamboo based products that can be used in construction application [1].

Bamboo can be used to make all the constituents of small buildings, both structural and nonstructural, except for of fireplaces and chimneys. On the other hand, often used in conjunction with other materials. Bamboo building construction is considered by a structural frame approach similar to that applied in timber frame construction. Bamboo is applicable in a

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variety of engineering fields including landscape, civil and chemical engineering. It is a strong raw material for construction. Bamboo has found uses in manufacturing pulp and paper, panel products, construction material, high strength fiber composites and an array of modern new generation bamboo products, used whole for construction and scaffolding, roofs and walls of houses, fencing, domestic and agricultural implements, water containers, food and drink containers hats, arrows, quiver, livestock shelters, temporary dwellings, parts of traditional houses, durable mats for building construction and fencing material. In this case, the floor, wall and roof elements are interconnected and often one dependent on the other for overall stability. There is a requirement to control lateral deformations in some traditional forms of building in particular. The competence and suitability of the building for occupancy will also depends to a large extent on good detailing, for example, to help prevent water and moisture ingress, fungal attack and vermin infestation [24].

2.13. Factors of Technology Transfer in Bamboo House Construction

The following are factors of technology transfer in the bamboo house construction sector [2].

- Inadequate technologies and weak technology transfer
- Lack of working capital
- High transportation costs of raw material
- Low quality products
- Poor networking among bamboo value chain actors
- Lack of skills and tools for processing bamboo
- Lack of a clear bamboo conservation and utilization policy
- Lack of economic incentives to promote rural communities to value bamboo as a useful commodity
- lack of modern processing technologies

2.14. Bamboo Utilization in Ethiopia

A huge range of bamboo products that are excellent alternatives for timber-produced materials has also been innovated. Based on the current bamboo industrial uses and the practical availability in the world, the commercial usages of bamboo resources at an industrial scale are characterized in the following serial of products: bamboo flooring and furniture, bamboo plywood for housing and bamboo molding board for concrete, in bamboo housing [25]. Although some people (particularly in Benshangul Gumuz National Regional State) use bamboo shoots in their diet, there are no data accessible to quantify the exact amount used and a way to deal with in this regard [26].

Despite the multiple uses of bamboo in industrial applications, up to now Ethiopia is not getting the most economic advantage out of it. The utilization is fully for domestic use. The low level of its utilization among others entails lack/absence of processing technologies and technologies to keep bamboo products from biological and physical damages. Hence, it has got fewer acceptances by both potential investors and growers [4].

2.15. Challenges of Bamboo Improvement in Housing Construction

Challenges for bamboo improvement in housing construction are as follows [27].

2.15.1. Lack of expertise in bamboo processing and construction among stakeholders

Professionals in the building industry are used to designing and building with other conventional materials such as concrete, steel, and to some extent wood. Experiences increased by several stakeholders have been on their personal use of the material over time without tolerable technical information about the material's properties and behavior. Technical data on the bamboo species available for use have not been made accessible to architects and engineers for consideration in the design and construction of houses.

2.15.2. Lack of promotion of bamboo houses

Bamboo houses have not been promoted due to many factors including poor finishing of existing bamboo houses in the country. The houses are usually built by villagers or poor farmers who deficiency the resources and technical know-how in building with bamboo or laminated boards. The bamboo is used raw without value addition and proper chemical treatment to make them durable. Deficiency of design and aesthetic considerations make the houses despicable. The

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available houses are poorly finished and do not promote the use of bamboo. Unavailability of processing equipment and tools equipment and tools for processing bamboo are not available. Large scale wood processing companies have participated in equipment and tools for wood processing and heavily export wood and wood products. However, bamboo processing machines are missing in the industry. The same machines used in processing wood are currently being used in the processing bamboo. This makes processing of bamboo difficult, ergonomically hazardous and laborious, hence a lack of value addition to bamboo. This also gives to the poor finishing of bamboo products as compared to bamboo products from other parts of the world.

2.15.3. Lack of commitment of stakeholder institutions/government

There is deficiency of synergy and collaboration among stakeholder institutions in promoting and enhancing the use of bamboo in the country. There is no direct link between research institutions and industry or NGOs working with bamboo. The commitment of the government in funding bamboo research and development has been low. There is no specific policy on bamboo as raw material and its utilization, especially in housing. Support to state organizations to set up bamboo processing and resource centers are not available. Additionally, there is a general deficiency of commitment by various stakeholders (industry, government, professionals, NGOs, private enterprises, individuals) on bamboo usage despite the suitable properties bamboo possesses for housing [28].

2.15.4. Lack of innovation

Innovation in the bamboo sector is important because of the need for substantial value addition from raw material to the final product and the diversity of product ranges. At this time, most of the products are traditional, lack diversity and are of poor quality. However, to upgrade the value chain, to compete with alternative products and to enter global markets, there is a need for constant innovation starting from raw material to market.

2.15.5. Lack of awareness

There is a general lack of awareness of the potential of bamboo. Bamboo is perceived as a cheap and less durable product. This is due to a lack of advanced skill and technology quality control device, lack of standards and the preservation and treatment of bamboo.

2.15.6. Lack of incentives

MSMEs and industries producing bamboo products are treated on par with mature industries, such as timber, plastic, or steel enterprises. There are no additional incentives for bamboo MSMEs and industries to enable them to compete with well-matured competitive sectors.

2.15.7. Lack of finance

Banks and financial institutions are not well aware of the profit-making cycle of bamboo and its potential, and this constrains the availability of finance for MSMEs and industry [19].

2.16. Major Factors Affecting Bamboo Application in the Construction Sector

To find out the characteristic factors affecting the application of bamboo, a comprehensive content analysis was accompanied. As a result, a list of typical literature that addressed various factors was found. By reviewing these research works, the factors were classified into three categories: technology-related, application-related, and policy-related barriers [18].

2.16.1. Application related factors [18]

- Low level of industrialization for production
- Lack of recognition and policy incentives from the government
- Lack of industrial planning and marketing planning for bamboo application
- limited knowledge on cultivation of good bamboo
- Lack of research funds for bamboo building materials
- Lack of leading enterprises
- No unified education system of bamboo and wood structure
- Lack of industrial associations and construction certification bodies
- Lack of promotion
- Less awareness of bamboo's potential benefits

2.16.2. Policy related factors [18]

- Lack of code of practice in the bamboo industry
- Lack of incentive policy
- No mechanism for technology transfer
- No certification mechanism for bamboo

2.17. Summary

- ⇒ The species bamboo is under evaluation in different parts of the country including specific localities known as Assosa, Injibara, Hagere-Selam, Debre-Zeit and Wondo-Genet [4].
- ⇒ The benefits of using bamboo for construction do not end with technical advantages only. It is very economical because it is a local product and therefore amongst the cheapest building materials [6].
- ⇒ Decades of research by bamboo practitioners have validated that, when treated and used properly, bamboo is a sound structural and engineering material, which, due to its strength, flexibility and versatility, is an appropriate material for use in housing [9].
- ⇒ Transfer of technology in bamboo construction is essentially for the spread of know-how to suit local conditions, effective absorption, and diffusion both within a country just one source of growth and strength for individual enterprises [18].
- ⇒ Traditional uses of bamboos like:- bamboo house, shade house, construction frame, door and window frames, bridges, Fencing, ladder, scaffolding partition walls etc. and modern uses of bamboo such as composites or wood substitutes bamboo mat board, flattened bamboo boards, bamboo jute composites, bamboo flooring, plywood, particleboard, fiber board prefabricated houses [1].
- ⇒ Bamboo can be used to make all the constituents of small buildings, both structural and nonstructural, except for of fireplaces and chimneys. It is, however, often used in conjunction with other materials. Bamboo building construction is described by a structural frame approach similar to that applied in timber frame construction [25].

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- ⇒ Inadequate technologies and weak technology transfer, lack of working capital, high transportation costs of raw material, low quality products etc. are factors of technology transfer in the bamboo house construction sector [2].
- ⇒ The modern bamboo industrial uses and the technical availability in the world, the commercial usages of bamboo resources at an industrial scale are categorized in the following series of products: bamboo flooring and furniture, bamboo plywood for housing and bamboo molding board for concrete [27].
- ⇒ Challenges for bamboo improvement in housing construction are lack of expertise in bamboo processing and construction among stakeholders, lack of promotion of bamboo houses, lack of commitment of stakeholder institutions/government, lack of innovation, lack of awareness, lack of incentives and lack of finance [28].
- ⇒ The factors affecting the application of bamboo were found out while reviewing various literatures. From the accessed research works, the factors were classified into three categories: technology-related, application-related, and policy-related barriers [19].

2.18. Identified Gaps

1. Technologies for efficient utilization of bamboo products are not practically applied by the people [4].
2. Bamboo housing technologies are not adopted to solve the problems of the wider housing needs [9].
3. Bamboo housing technology transfer mechanism is not practiced in the construction industry [19].

CHAPTER THREE

RESEARCH METHODOLOGY

3.1. Study Area Selection

The rural area is selected due to various reasons. Awi has managed the bamboo production system due to the accessibility of bamboo forest. The study place is the major bamboo growing area that has diverse craft production and utilization culture, the intensity of household consumption and level of market integration. The area is selected based on the major users of commercial bamboo resources and the main traditional bamboo handcraft processing centers. The selected area is more or less illustrative for the Ethiopian bamboo growing and processing places and later provides useful reasonable insight in to bamboo products and technologies. Generally, Awi is located in an accessible area that facilitates data collection in a possibly shortest time.

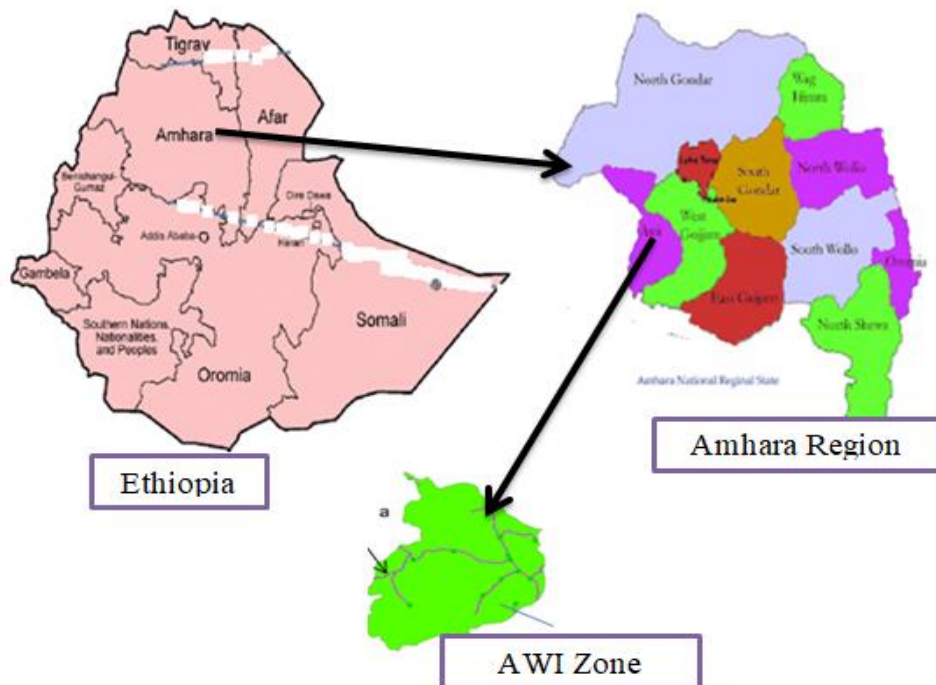


Figure 3. 1: Location of the study area [32]

3.2. Study Area Description

The study area is Awi, Ethiopia, which is found in the Amhara Region. Awi is one of the administrative zones of the Amhara Regional State of Ethiopia. It is located at 10027' and 11025' N latitude 36017' and 3704' E longitude with an altitudinal range of 1900- 3300 m.a.s.l. and an average temperature of about 18°C and rainfall of 2206 mm. The population of the Zone is 1,077,144 and the majority of the Zone is cooler with rich bimodal rainfall. Bamboo grows in the highlands and lowlands. Awi is situated on the highway from Addis Ababa to Bahir Dar which is another flourishing city in the northwestern part of the country. Thus, it is well interrelated by all-weather roads and communities can easily transport their products to market or depletion centers. Also, Awi is moderately at a distant from Addis Ababa of 552 km, it is surrounded by neighboring other cities such as Bahir Dar (114 km), Debre Markos (141 km), and Gondar (172km). Awi has an area of 9,148.43 square kilometers and it is one of the major agricultural manufacture areas in Northwestern Ethiopia [30].

3.3. The Research Approach

Research is a process of collecting consistent data and interpreting those to real information to provide results to persisting questions. The research is defined as a practical examination or exploration to find out new facts or assemble old facts by scientific ways by applying existing theory or its application tackle real problems. In this research qualitative and quantitative analysis was used to simplify facts starting from specific facts and ideas based on observed problems and existing theories [31].

3.4. Primary Source of Data

I. Questionnaire

The questionnaire is one the effective and appropriate data collection tools. More information can be obtained from many numbers of members and this can increase the precision of the result. Accordingly, the major data collection tool for this study was a structured questionnaire which is composed of important questions. The questions were focused on the research specific objectives leading to answering the questions raised and quantitative method have been used to analysis the data. To get a high level of response, clear, precise and logically structured questions were prepared and finally the numbers of questions were decided based on the feedback of the study.

II. Interview

It is an effective means of data collection method mainly for qualitative data in this research to get raw facts, practices and real situations based on raw data gained from the respondents. In nondirective type of interview the interviewer asks questions as they come to mind [40]. On the other hand, in the structured or directive interview the questions are stated in advance. In this research, bamboo housing construction and the technology transfer practice for construction was focused upon.

III. Case study

Case studies would be made on selected craft enterprises, medium-sized bamboo producing stakeholders and bamboo houses. Multiple data collection techniques will be preferred to understand the context and make the participant s' response with practically high validity [32].

3.5. Secondary Source of Data

In this study the secondary sources of data were obtained from relevant books, journals and research papers which were reviewed to gain knowledge on the subject of bamboo in housing construction; particularly, on bamboo as a house construction material. The relevant literature were undertaken to develop an understanding of bamboo in housing construction projects and previous research concerned with bamboo have been consulted to identify the major points, ideas and issues to be included in the data collection and analysis for the research [33].

3.6. Target Population

The term population refers to the collective or totality of all the objects, subjects, or members that conform to a set of qualifications. In quantitative studies, the researcher identifies the population to be studied during the planning phase. A smaller population can be studied more extensively at a fixed cost than a larger population, so it is important to decide what population is really of critical importance. To select a right sample from a given set of population random sampling were used. The population was used from stakeholders (owner, professional and regulatory bodies) who work in awi zone bamboo house construction. After the baseline survey was complete, semi-structured questioners, interviews and case studies were conducted on bamboo houses, bamboo craft enterprises, bamboo enterprises and other consumers and bamboo experts [34].

3.7. Sample Size Determination

Sampling is the process of selecting representative units of construction parties for the study. The advantage of using a sample is that it is more practical and less costly than collecting data from all the construction parties. The population of the study was stakeholders working in Awi Zone bamboo products are a total of eighty (80). The following equation had been used to determine the sample size [35].

$$no = (p*q) / V^2 \dots\dots\dots (3.1)$$

$$n = no / [1 + (no / N)] \dots\dots\dots (3.2)$$

Where:

no: First estimate of sample size

p: The proportion of the characteristic being measured in the target population with value of 0.5

q: Complement of p or 1-p

V: The maximum standard error allowed

N: The population size

n: The sample size

3.8. Methods, Tools and Instruments Used for the Research

The qualitative data was collected through interviews and case studies which were analyzed based on the specific objectives of the study. Further, the data related to the current local practice was interpreted to the theoretical implication and was compared with the global practice of bamboo housing construction by using detailed description and in-depth discussion. Quantitative data was collected through questionnaires and the analysis uses for order of mathematical operations to evaluate the properties of data [38]. Quantitative data obtained from the respondents were fed into the SPSS sheet to calculate and process the data. Later it was analyzed using the Statistical Package for Social Sciences (SPSS) and mean score to obtain ranks of the results [39]. To analyze the data, first the data were collected from respondents is fed into SPSS, then mean of concerned individual stakeholders have been calculated, finally the mean values were analyzed. Finally, the obtained results were analyzed and discussed with respect to the theoretical background to highlight the finding of the study as well as to draw a conclusion.

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Validity is concerned with whether the question or score can measure what it is supposed to measure. Validity has different aspects and assessment approaches. Statistical validity is used to evaluate instrument validity, which includes content validity and statistical validity. For this research, statistical validity was used Statistical Packages for the Social Sciences (SPSS). For validation purposes, it could be distributed questionnaires. The reliability of the result has been checked by Cronbach's alpha to know the measure of internal consistency ("reliability"). It is most commonly used when you have multiple Likert scales in a questionnaire that forms a scale and wish to determine if the scale is reliable. Some researchers also offered indications of alpha having a threshold or cut-off as an acceptable, sufficient or satisfactory level [37].

Table 3. 1: Cronbach's alpha range and scale [37]

Range	Scale
0.93–0.94	Excellent
0.91–0.92	Strong
0.84–0.90	Reliable
0.81–0.83	Robust
0.76–0.80	Fairly high
0.73–0.75	High
0.71–0.72	Good
0.70–0.71	Relatively high
0.67–0.69	Slightly low
0.64–0.66	Adequate
0.61–0.63	Moderate
0.58–0.60	Satisfactory
0.45–0.57	Acceptable
0.40–0.44	Sufficient
0.20–0.39	Not satisfactory
0.11	Low

3.9. Research Design

Research design is the overall plan for obtaining answers to the questions being studied and for handling some of the problems met during the study process and initial set of questions to be answered [3535].

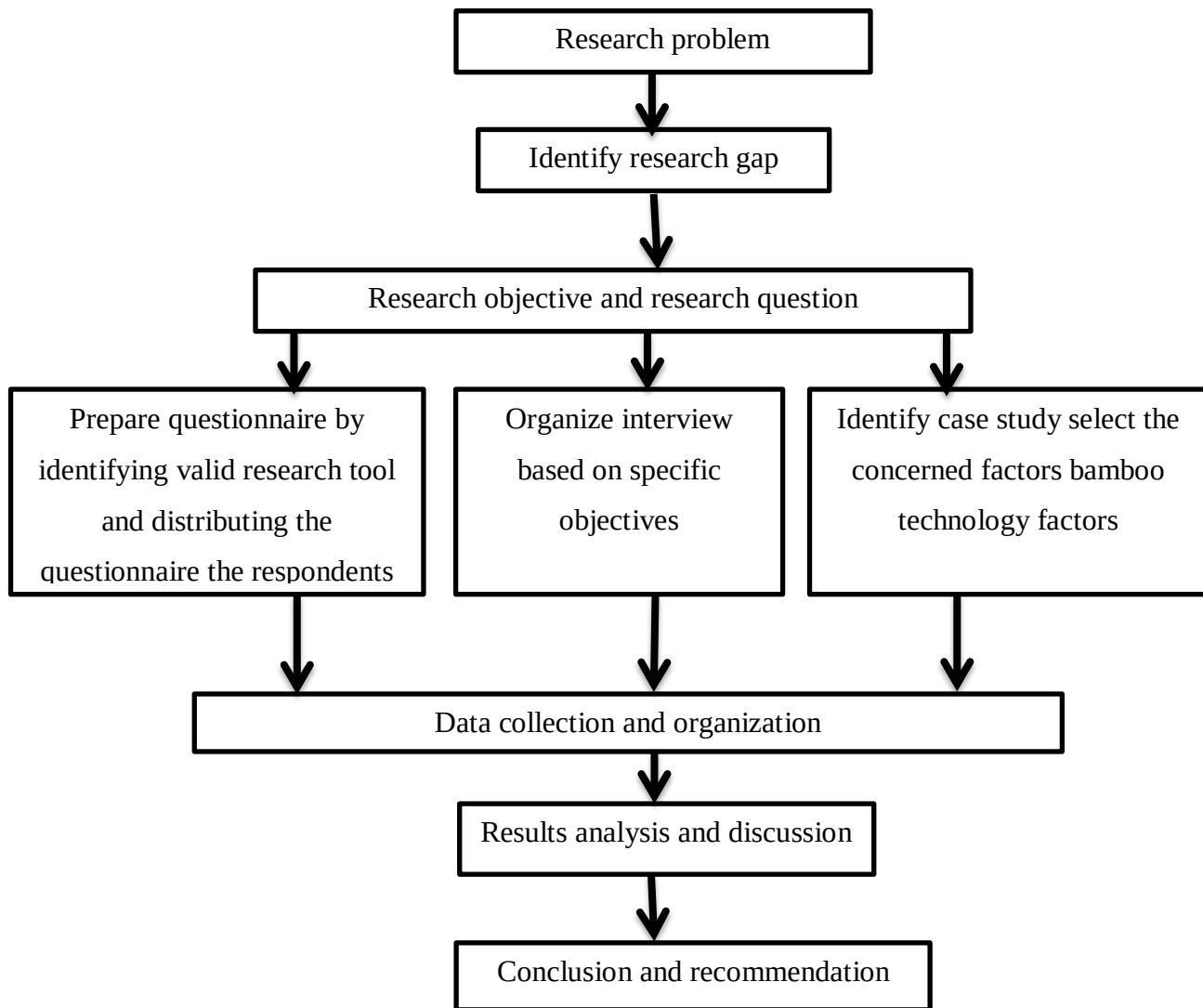


Figure 3. 2: Research work flow (researcher's own design)

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1. Introduction

This chapter focuses on analyzing and interpreting of the data and results collected from the respondents through questionnaire, interview and case studies. The data collected from the respondents could be used to identify the actual practice of bamboo house construction technology. The comparison of the results is interpreted based on information gained from questionnaires, personal interviews and site observation data.

4.2. Questionnaire Response Rate

During the survey, different individuals were consulted in order to fulfill the objective of the research. Based on equation 3.1 and 3.2 first estimate of sample size $(n_0) = 0.5 \cdot (1 - 0.5) / 0.04^2 = 156$ and the sample size $(n) = 156 / [1 + (156/80)] = 52$. For analysis purposes 52 questionnaires were distributed to concerned stakeholders among them only 46 questionnaires were filled and returned effectively as shown in table 4.1 below.

Table 4. 1: Questionnaire response rate

Stakeholders	Questionnaire distributed		Questionnaire returned		Response rate
	No	%	No	%	%
Owner	18	34.62	17	36.96	94.44
Professional	29	55.77	26	56.52	89.65
Regulatory body	5	9.61	3	6.52	60
Total /average	52	100	46	100	81.36

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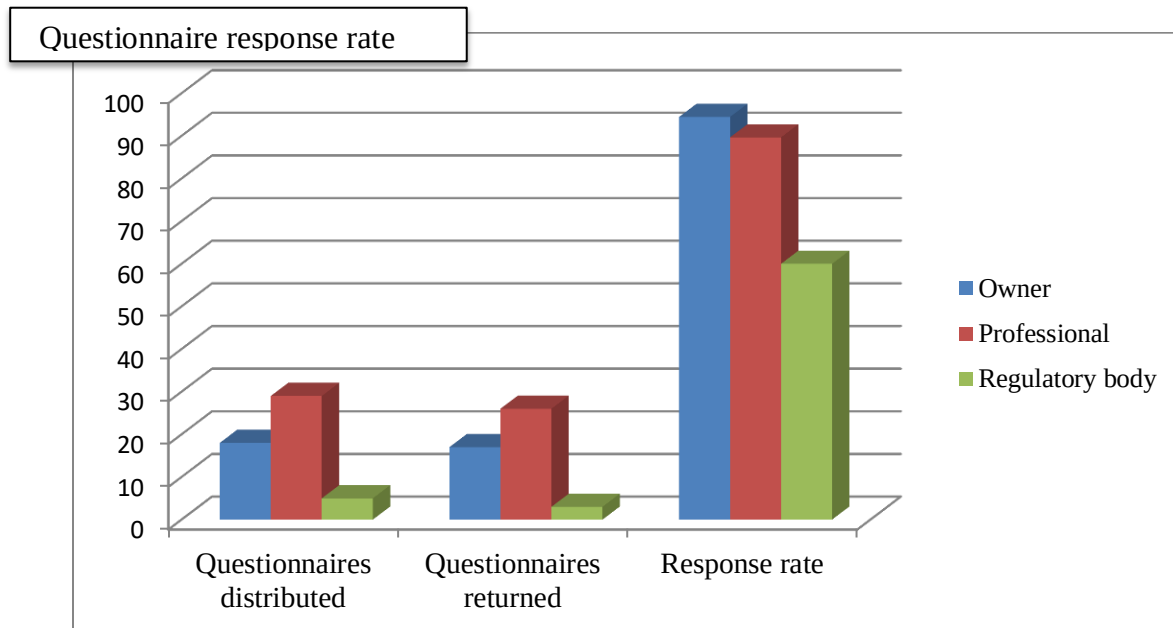


Figure 4. 1: Questionnaire response rate

4.3. General information of Respondents

For this study concerned stakeholders were owners, professionals and regulatory body questionnaires were distributed and returned from respondents who worked on bamboo products with a different purpose, level of education and experience.

4.3.1. Educational Level of Respondents

Table 4. 2: Educational level of respondents

Stakeholders	Level of Education									
	PhD		MSc		BSc		Diploma		TVET (Certificate)	
	No	%	No	%	No	%	No	%	No	%
Owner	0	0	0	0	3	27.27	5	34.71	2	9.52
Professional	0	0	0	0	6	54.54	8	57.14	19	88.47
Regulatory body	0	0	0	0	2	18.18	1	7.14	0	0
Total/average	0	0	0	0	11	33.33	14	33.33	21	48.99

Table 4.2 indicates the level of education of respondents, according to this table total/average percentage PhD and MSc weights 0%, diploma and bachelor degree levels weights 33.33% and

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TVET weights 48.99%. From these results it is possible to conclude that most professionals who work in bamboo products are certificate holders.

4.3.2. The Experience of Professionals

Table 4. 3: The experience of professionals

Years of Experience									
1-2		3-4		5-6		Above 6		Total	
No	%	No	%	No	%	No	%	No	%
5	10.87	4	8.7	15	32.61	22	47.83	46	100

Experience in construction is significant, as the result shows the experience of professionals above 6 years are 22(47.83%) , 5-6 years are 15(32.61%), 3-4 years are 4(8.7%) and 1-2 year are 5(10.87%) . Therefore, many professionals in the bamboo product have an experience of above 6 years and only few professionals have an experience between 3 and 4 years.

4.4. Challenges of bamboo improvement in housing construction

To show the challenges bamboo improvement in housing construction sector respondents were asked about all the seven challenges bamboo improvement in construction.

Table 4. 4: Mean of challenges bamboo improvement in housing construction

Challenges Bamboo Improvement in Housing Construction	N	Mean
Lack of promotion of bamboo houses	46	3.37
Lack of expertise in bamboo processing and construction among stakeholders	46	3.41
Lack of commitment of stakeholder institutions/government	46	3.80
Lack of awareness	46	3.83
Lack of incentives	46	3.85
Lack of innovation	46	3.87
Lack of finance	46	4.11
Reliability Statistics (α)		0.550

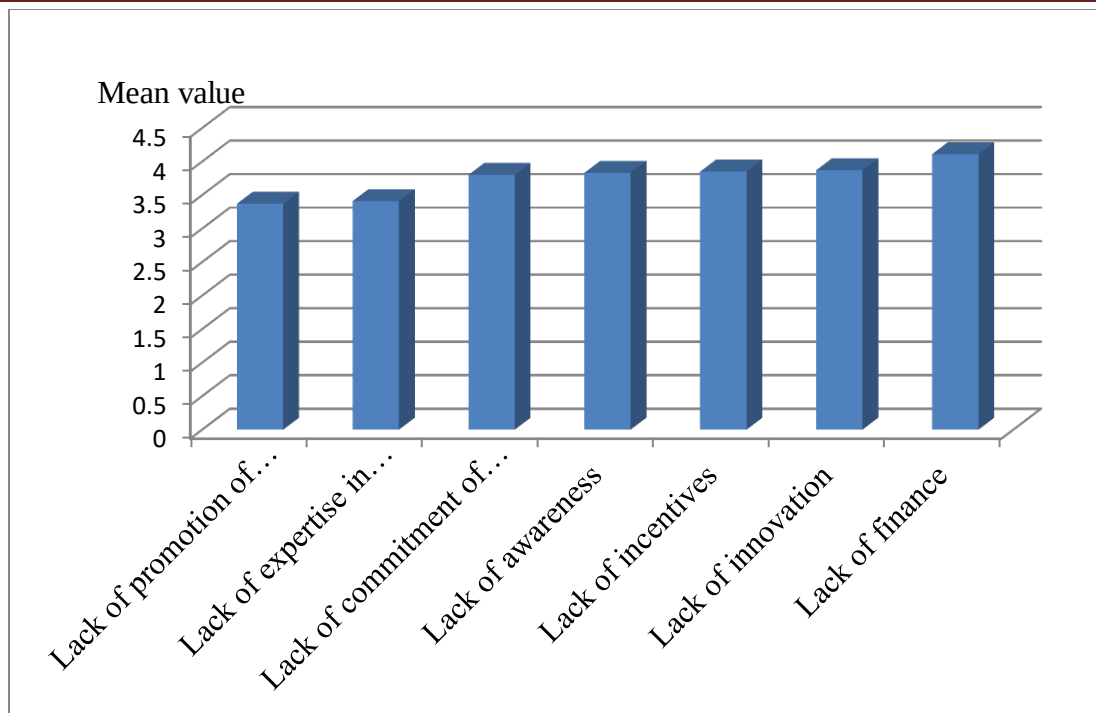


Figure 4. 2: Challenges bamboo improvement in housing construction

As the response obtained from the respondents on the challenges bamboo improvement the reliability statistics Cronbach's Alpha value (0.550) is acceptable with the largest mean score value of 4.11. As per the result that is presented above the top five challenges bamboo improvement based on their mean values are lack of finance with 4.11, lack of innovation with 3.87, lack of incentives with 3.85, lack of awareness with 3.83 and lack of commitment of stakeholder institutions with 3.80. The rest are of minor challenges bamboo improvement in housing construction.

4.5. Major Factors Affecting Bamboo Application

The major factors affecting bamboo application is categorized in to two major groups like, application- related factors and policy - related factors. The result of each factor is summarized separately in the form of tables and figures.

Investigation of Traditional Bamboo House Construction Practice and the Need for Bamboo House Construction Technology in Awi Zone

4.5.1. Application related factors in bamboo use

Table 4. 5: Application related factors in bamboo use

Application related factors of bamboo	N	Mean
Lack of recognition and policy incentives from the government	46	3.63
Lack of leading enterprises	46	3.74
Less awareness of bamboos potential benefit	46	3.78
Lack of industrial planning and marketing planning for bamboo application	46	3.85
Lack of promotion	46	3.87
Low level of industrialization for production	46	3.87
no unified education system of bamboo and wood structure	46	3.89
limited knowledge on cultivation of good bamboo	46	3.89
lack of industrial associations and construction certification bodies	46	4.02
Lack of research funds for bamboo building materials	46	4.22
Reliability Statistics (α)		0.561

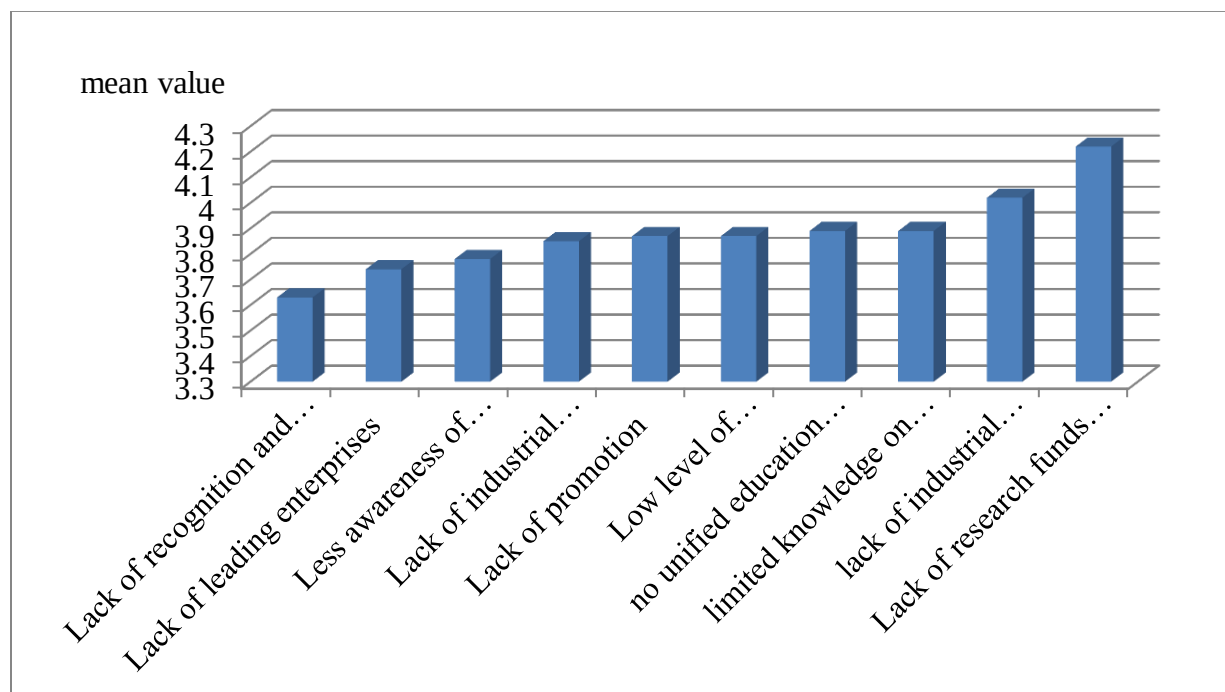


Figure 4. 3: Application related factors in bamboo use

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The above table shows that lack of research funds for bamboo building materials with a mean of 4.22, lack of industrial associations and construction certification bodies with a mean of 4.02, limited knowledge on cultivation of good bamboo with a mean of 3.89, no unified education system of bamboo and wood structure with a mean of 3.89, low level of industrialization for production with a mean of 3.87, lack of promotion with a mean of 3.87, lack of industrial planning and marketing planning for bamboo with a mean of 3.85 are the top seven major factors in bamboo application with a fairly high reliability Alpha value (0.561) with highest mean score of 4.22. While the rest of all other are minor factors in the bamboo house construction sector.

4.5.2. Policy related factors in bamboo application

Table 4. 6: Policy related factors in bamboo application

Policy related factor of the bamboo application	N	Mean
Lack of code of practice in the bamboo industry	46	3.35
No mechanism for technology transfer	46	3.46
Lack of incentive policy	46	3.87
No certification mechanism for bamboo	46	4.13
Reliability Statistics (α)		0.126

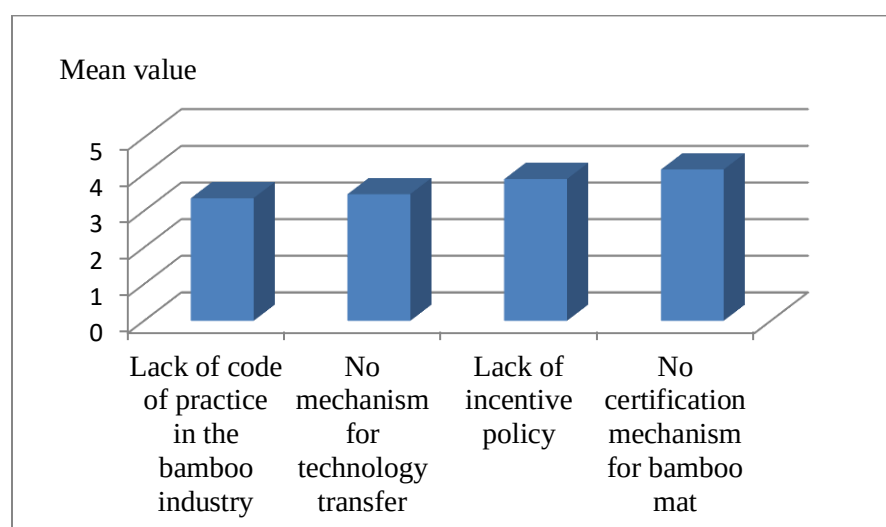


Figure 4. 4: Policy related factors in bamboo application

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As the response obtained from the respondents on policy related factors in bamboo application has low reliability (0.126) with the highest mean score value of 4.13. The above table shows that no certification mechanism for bamboo mat with a mean of 4.13, lack of incentive policy with a mean of 3.87, no mechanism for technology transfer with a mean of 3.46 and lack of code of practice in the bamboo industry with a mean of 3.35 are the top four major factors in bamboo application under policy related factors.

4.6. Factors of Technology Transfer in Bamboo Construction

From the literature review, it has been found that factors of technology transfer in the bamboo house construction sector respondents were asked to score every ten factor of technology transfer in bamboo construction for a clearer picture of the practice.

Table 4. 7: Factors of technology transfer in bamboo construction

Factors of Technology Transfer in Bamboo Construction	N	Mean
High transportation costs of raw material	46	3.43
Lack of a clear bamboo conservation and utilization policy	46	3.48
Poor networking among bamboo value chain actors	46	3.48
Lack of working capital	46	3.50
Lack of skills and tools for processing bamboo	46	3.52
Low quality products	46	3.57
lack of modern processing technologies	46	3.74
Lack of economic incentives to promote rural communities to value bamboo as a useful commodity	46	3.83
Inadequate technologies and weak technology transfer	46	4.13
Reliability Statistics (α)		0.218

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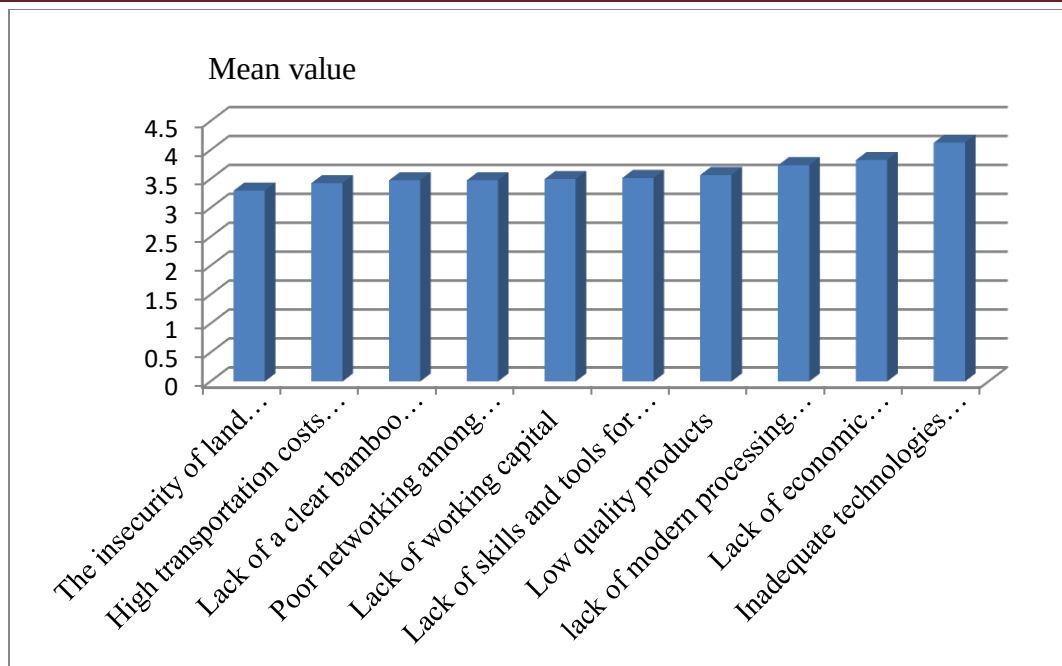


Figure 4. 5: Factors of technology transfer in bamboo construction

As the response obtained from the respondents on eleven factors of technology transfer in bamboo construction Cronbach's alpha value reliability is satisfactory of 0.218 with the maximum mean score of 4.13. The above table shows that, inadequate technologies and weak technology transfer with 4.13, lack of economic incentives to promote rural communities with 3.83, lack of modern processing technologies with 3.74, low quality products with 3.52 and lack of skills and tools for processing bamboo with 3.50 are top five factors of technology transfer in bamboo construction. While the rest of all other are minor factors of bamboo construction technology transfer.

Investigation of Traditional Bamboo House Construction Practice and the Need for Bamboo House Construction Technology in Awi Zone

4.7. Current Use of Bamboo in Housing Construction

4.7.1 Traditional use of bamboo in Awi Zone

Table 4. 8: Traditional use of bamboo in Awi zone

Traditional use of bamboo in Awi Zone	N	Mean
walls	46	3.07
doors and windows	46	3.43
fences	46	3.59
roofing	46	3.61
shade house	46	3.65
furniture	46	3.65
basketry	46	3.67
household utensils	46	3.83
mats	46	3.83
rudimentary furniture	46	3.85
flooring	46	4.54
Reliability Statistics (α)		0.442

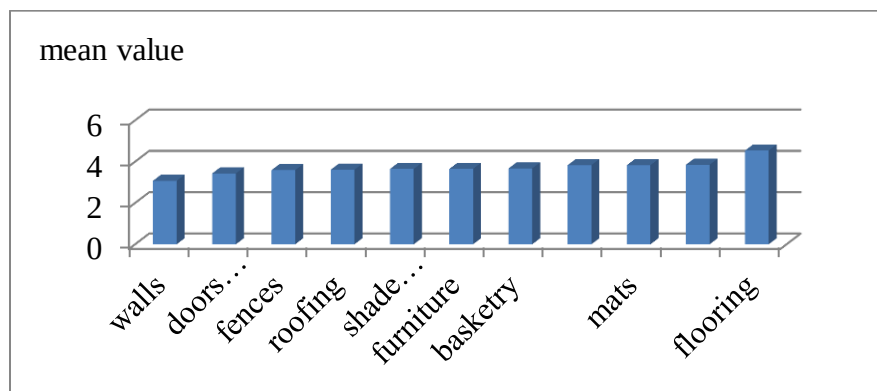


Figure 4. 6: Traditional use of bamboo in Awi Zone

Investigation of Traditional Bamboo House Construction Practice and the Need for Bamboo House Construction Technology in Awi Zone

As a result shown above, has sufficient reliability of 0.442 with a peak mean of 4.54. The most products of bamboo used for flooring, rudimentary furniture, mats, basketry and household utensils in a traditional manner.

4.7.2. Contemporary use of bamboo in Awi Zone

Table 4. 9: Contemporary use of bamboo in Awi Zone

Contemporary use of bamboo in Awi Zone	N	Mean
foundation	46	2.93
ceiling	46	3.15
bamboo jute composites	46	3.28
bamboo flooring	46	3.37
bamboo mat board	46	3.39
man-hole covers	46	3.41
fiber board prefabricated houses	46	3.57
scaffolding	46	3.61
flattened bamboo boards	46	3.63
plywood	46	3.70
particle board	46	3.85
Reliability Statistics (α)		0.487

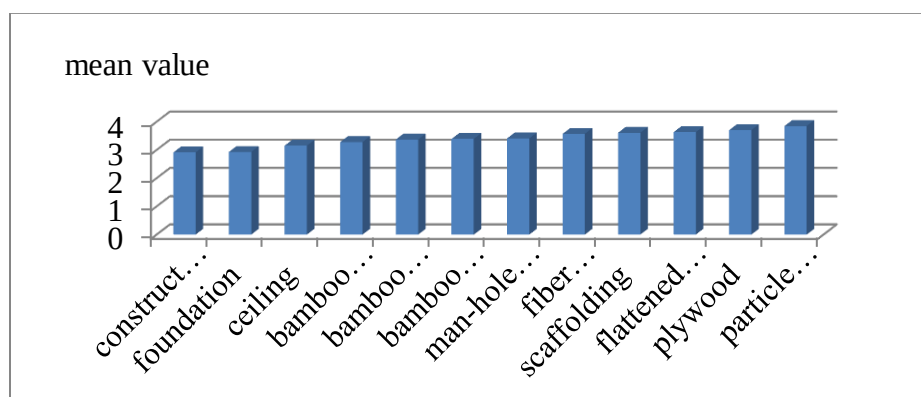


Figure 4. 7: Contemporary use of bamboo in Awi Zone

Investigation of Traditional Bamboo House Construction Practice and the Need for Bamboo House Construction Technology in Awi Zone

As the results in the above show, reliability (0.487) is acceptable with 3.85 higher mean score value. Most products of bamboo are used for particle board, plywood, flattened bamboo boards, scaffolding and fiber board prefabricated houses contemporarily.

4.8. The Results of Interview Questions

- ❖ The main challenges of bamboo innovation in house construction obtained from the interviews are stated below.

Tabel 4. 10: Challenges of bamboo innovation in house construction

Challenges of bamboo innovation in house construction	Yes (%)	No (%)	Rank
Lack of bamboo house promotion	49	51	5
Lack of government support to develop bamboo house technology	52	48	3
Low interest in bamboo house construction	61	31	2
Lack of working capital	48	52	6
Inadequate machines and tools to work bamboo house	72	28	1
Lack of adequate education and skills	51	49	4

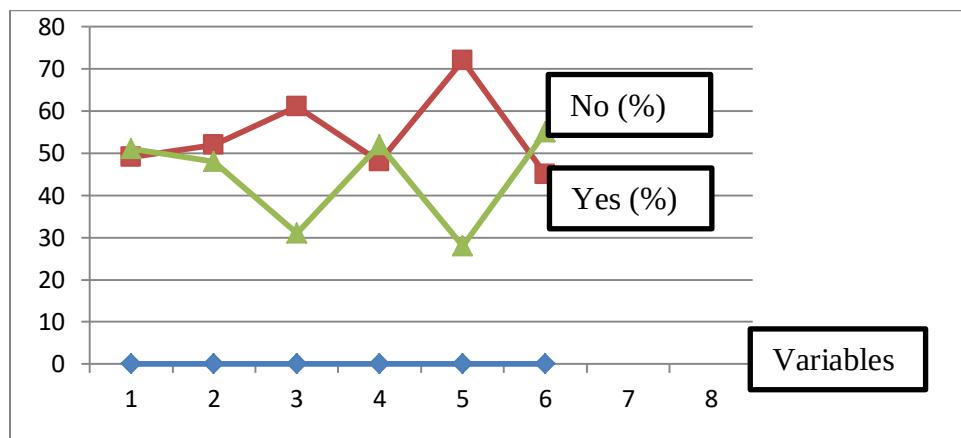


Figure 4. 8: Challenges of bamboo innovation in house construction

Based on the results of interview questions, inadequate machines and tools to work bamboo house (72%), low interest in bamboo house construction (61%), Lack of government support to develop bamboo house technology (52%) and lack of adequate education and skills are the main factors of technology in bamboo house construction.

Investigation of Traditional Bamboo House Construction Practice and the Need for Bamboo House Construction Technology in Awi Zone

4.9. Case Study

The case study were conducted to the site practice problem of bamboo house construction and Factors of bamboo enhancement in housing construction on selected stakeholders as presented below. The methods of analysis were based on the percentage of the respondents.

Tabel 4. 11 :Site practice problem of bamboo house construction

Case study I: Site Practice Problem of Bamboo House Construction	Yes (%)	No (%)	Rank
Have you used harvested bamboo in dry season to avoid fungus attack and excess moisture?	55	45	4
Have you used chemical treatments in row materials of bamboo?	17	83	1
Have you protect bamboo materials from direct sun, moisture and rain?	44	56	3
Did you encourage peoples to use bamboo for house construction?	72	28	5
Did you get training on the ways of bamboo house construction?	23	77	2
Case study II: Factors of Bamboo Enhancement in Housing Construction			
Lack of strategy, implementation and integration on bamboo materials	59	41	2
weak linkage between different institutions	45	55	6
Limited management system of bamboo resource	42	58	8
Improper use of bamboo materials for house building	48	52	5
Lack of systematic experimental research	62	38	1
Inadequate bamboo processing techniques	49	51	4
Difficulty in forming storing joints	52	48	3
Difficulty in quality control	44	56	7

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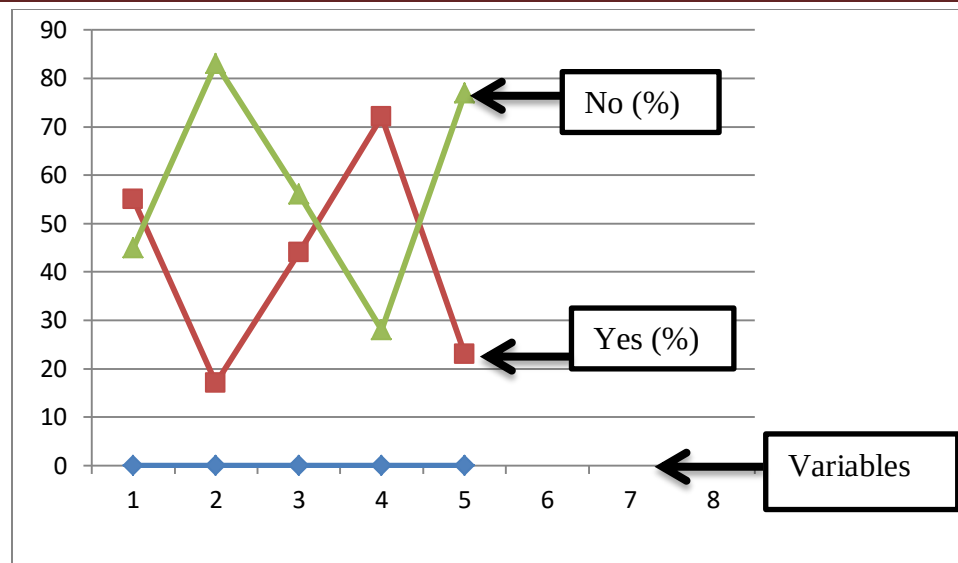


Figure 4. 9: Site practice problem of bamboo house construction

From case study I, chemical treatment of bamboo materials were not used (83%) , lack of training on the ways of bamboo house construction(77%), protect bamboo materials from direct sun, moisture and rain were not adopt(56%) are the main problems of house construction technology implementation based on the ranks of respondents saying no.

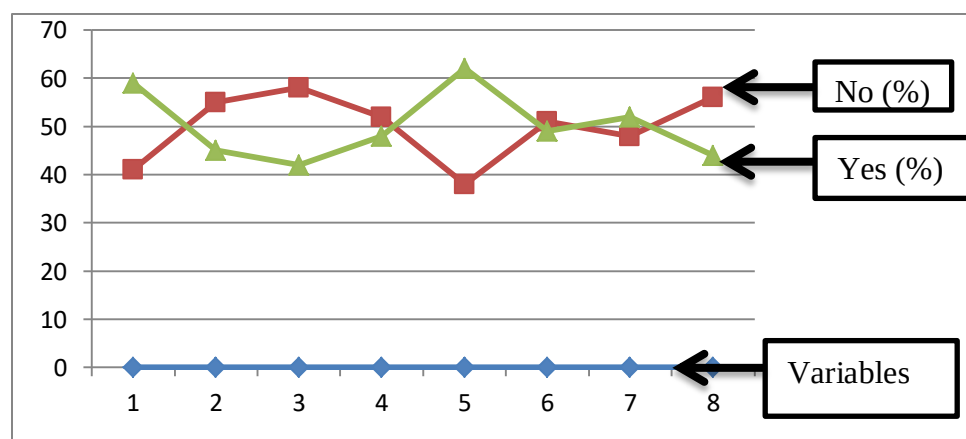


Figure 4. 10: Factors of bamboo enhancement in housing construction

From case study II, Lack of systematic experimental research (62%), lack of strategy, implementation and integration on bamboo materials (59%), difficulty in forming storing joints (52%) and inadequate bamboo processing techniques (51%) are the main factors of bamboo enhancement in housing construction based on the ranks of respondents saying yes.

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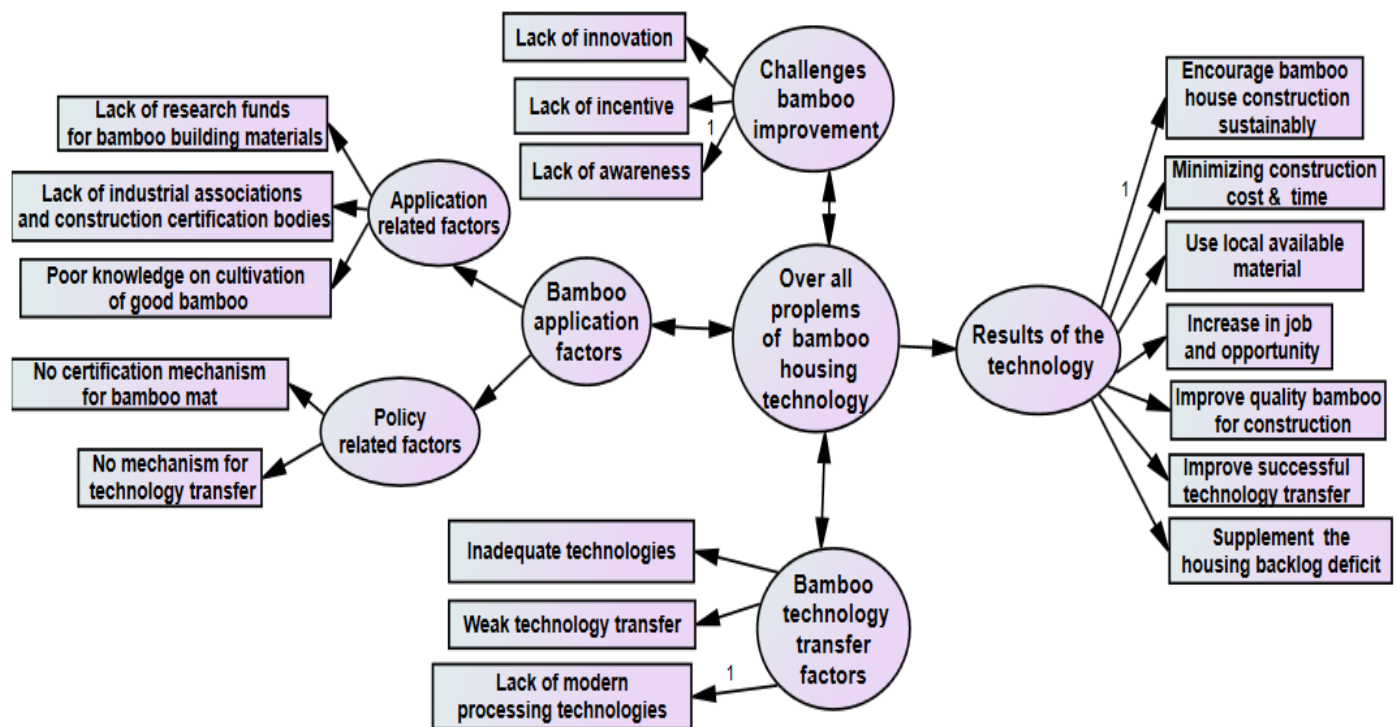


Figure 4. 11: proposed technology transfer mechanism in bamboo house construction technology (own compilation)

As shown in Figure 4.11, Technology transfer mechanism of bamboo house construction could be achieved when solving the problems of bamboo application factors, bamboo utilization challenges and bamboo technology transfer factors. The factors could be solved by planning and preparing adequate fund, conduct systematic research, starting small scale enterprises, avoiding poor knowledge on cultivation of bamboo, establishing incentive policy, create awareness and use contemporary processing technology. After solving such problems the final results would be to encourage bamboo house construction sustainably, minimizing construction cost and time, use local available material, increase in job and opportunity, improve quality of bamboo for construction, improve successful technology transfer and supplement the housing backlog deficit.

4.10. Summary of the Findings

4.10.1: Findings

In this section, the results of the questionnaire, structured interview and case studies were summarized from the perspectives of literature review on the technology of bamboo house construction to meet the objective of the study. The outcomes of the findings are summarized as follows:

- ❖ Lack of finance, lack of innovation and lack of incentives are the major challenges bamboo improvement in housing construction industry.
- ❖ Lack of systematic experimental research, lack of industrial associations and construction certification bodies, lack of research funds for bamboo building materials, poor knowledge on cultivation of good bamboo, lack of unified education system of bamboo and wood structure, no software to assist analysis and design, no certification mechanism for bamboo mat, lack of incentive policy are the major factors affecting bamboo application in housing construction sector.
- ❖ Limited technologies and weak technology transfer, lack of economic incentives to promote rural communities in the value of bamboo as a useful commodity and lack of modern processing technologies are also the major factors of technology transfer hindrances in the bamboo house construction industry.

4.10.2: Mitigation Measure

Allocating research funds for bamboo housing materials, use of adequate technologies and enhancing basic technology transfer are the main mitigation measures. In addition to this, it needs an attitudinal change of workers towards bamboo house technology through proper training, improving software to assist analysis and design of bamboo house and introduce incentive policy.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1. Conclusion

Conclusions are drawn from the study by combining the results and discussions leading to solving the problems. It was meant to answer the questions raised and the specific objectives stated in section 1.3.2 of the introduction chapter.

- ❖ Based on the finding, most products of bamboo are used for flooring, rudimentary furniture, mats, and basketry and household utensils in a traditional manner.
- ❖ The results indicated that, lack of financial support, lack of innovation and lack of incentives are the main challenges bamboo improvement in housing construction industry.
- ❖ This research revealed that the major factors affecting bamboo application are: lack of industrial associations and construction certification bodies, limited knowledge on cultivation of good bamboo, lack of unified education system of bamboo and wood structure and no certification mechanism for bamboo.
- ❖ The findings showed that, limited technologies and weak technology transfer, lack of economic incentives to promote rural communities and lack of modern processing technologies are the major obstacles of technology transfer in the bamboo house construction.

5.2. Recommendation

5.2.1. Government

1. Should promote and regulate with incentives to establish modern bamboo housing technology.
2. Should develop effective knowledge on good bamboo cultivation.
3. Should unify the concerned parties with guidelines on bamboo application as a vital resource.
4. Establish a mechanism of technology transfer from the international practice.

5.2.2. Regulatory body

1. Should provide initiatives of bamboo application both at the state and national level.
2. Should popularize missions of bamboo construction technology which could be derived from the national strategy.
3. Should unify polices and laws that can help the growth of bamboo construction.

5.2.3. Supporting agencies (research institutes, financial institutes, and civil societies)

1. Should provide financial aid and technical assistance to develop contemporary bamboo housing technology.
2. Should create awareness of bamboo use as a sustainable building construction material through their civil society.
3. Organize workshops for researchers to disseminate knowledge through sensitization and sharing of ideas.

5.2.4. Recommendation for future studies

1. Bamboo Materials Management in the Ethiopian Construction Industry.
2. Developing Bamboo Building Policy framework for the Ethiopian construction industry.

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APPENDIX A

Questionnaire Survey for Thesis paper on

**Investigation of Traditional Bamboo House Construction Practice and the
Need for bamboo Construction House Technology in Awi Zone**



**BAHIR DAR UNIVERSITY
INSTITUTE OF TECHNOLOGY
SCHOOL OF CIVIL AND WATER RESOURCE ENGINEERING
CONSTRUCTION TECHNOLOGY AND MANAGEMENT
DEPARTMENT**

QUESTIONNAIRES

Questionnaires prepared for bamboo house construction sector on the topic of **“Investigation of Traditional Bamboo House Construction Practice and the Need for bamboo Construction House Technology in Awi Zone”**

INTRODUCTION

This questionnaire is prepared to obtain relevant information from the concerned parties work on bamboo house construction and use. The information is required for academic research towards fulfilling the requirement of Master of Science in Construction technology and management on technology of bamboo housing construction. I kindly request your participation and support by providing the necessary information as input for this research. The main objective of this research is to investigate traditional bamboo house construction practice and the need for bamboo house construction technology in Awi Zone. Consequently; your response is highly relevant, valuable and contributors to the result of the research. All information will be used for academic research. This questioner is divided into five parts. The first part consists of personal and company general information. The second part consists of challenges bamboo improvement in housing technology. The third part involves identifying major factors affecting bamboo

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application and the fourth part consists of factors of technology transfer in bamboo use, while the last part of this questionnaire deals with the current use of bamboo in the Awi Zone construction sector.

RESEARCHER INFORMATION

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THANK YOU!

Part 1: Personal information

Instruction: Please select the best answer which suits to the issue raised and put (✓) mark inside the box or encircles the letter provided.

What is your position in the firm? Private enterprises,

☐ Owner

☐ Professional

☐ Regulatory body

Others-----

Your level of education

☐ TVET

☐ Diploma

☐ Bachelor Degree

☐ Master Degree

☐ Doctorate Degree

Others-----

Your total experience in your company

A.1-2 years B.3-4 years C.5- 6 years D. 6 years above

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Part 2: - Challenges of Bamboo Improvement in Housing Construction (CBIHC)

Instruction:-Listed below are challenges and gaps for bamboo utilization, Based on your experience in your project, please tick (✓) the appropriate box which indicates your level of agreement using a scale of 1-5. 1= very low, 2= low, 3 = medium, 4 = high, 5 = very high

CODE	Challenges of Bamboo Improvement in Housing Construction (CBIHC)	1	2	3	4	5
CBIHC1	Lack of expertise in bamboo processing and construction among stakeholders					
CBIHC2	Lack of promotion of bamboo houses					
CBIHC3	Lack of commitment of stakeholder institutions/government					
CBIHC4	Lack of innovation					
CBIHC5	Lack of awareness					
CBIHC6	Lack of incentives					
CBIHC7	Lack of finance					

Part 3: Major factors Affecting Bamboo Application (MFABA)

Group	CODE	Major Factors Affecting Bamboo Application	1	2	3	4	5
Applic ation related factors	MFABAA1	Low level of industrialization for production					
	MFABAA2	Lack of recognition and policy incentives from the government					
	MFABAA3	Lack of industrial planning and marketing planning for bamboo application					
	MFABAA4	Limited knowledge on cultivation of good bamboo					
	MFABAA5	Lack of research funds for bamboo building materials					
	MFABAA6	Lack of leading enterprises					
	MFABAA7	No unified education system of bamboo and wood structure					
	MFABAA8	Lack of industrial associations and construction					

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		certification bodies					
	MFABAA9	Lack of promotion					
	MFABAA10	Less awareness of bamboo's potential benefits					
Policy related factors	MFABAP1	Lack of code of practice in the bamboo industry					
	MFABAP2	Lack of incentive policy					
	MFABAP3	No mechanism for technology transfer					
	MFABAP4	No certification mechanism for bamboo					

Part 4: Factors of Technology Transfer in Bamboo Construction (FTTBC)

CODE	Factors of Technology Transfer in Bamboo Construction	1	2	3	4	5
FTTBC1	Inadequate technologies and weak technology transfer					
FTTBC2	Lack of working capital					
FTTBC3	High transportation costs of raw material					
FTTBC4	Low quality products					
FTTBC5	Poor networking among bamboo value chain actors					
FTTBC6	Lack of skills and tools for processing bamboo					
FTTBC7	Lack of a clear bamboo conservation and utilization policy					
FTTBC8	Lack of economic incentives to promote rural communities to value bamboo as a useful commodity					
FTTBC9	lack of modern processing technologies					

Part 5: Current Use of Bamboo in Housing Construction (CUB)

Instruction: Listed below are current use of bamboo as construction materials, please indicate the level of use in your project by putting '√' mark. The scale at the top of each values representing the following rates. 1 - Never , 2 - Rare ,3 - Some times ,4 - often ,5 - Always.

	Traditional use of bamboo	1	2	3	4	5
CUBT1	flooring					
CUBT2	walls					

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CUBT3	roofing					
CUBT4	fences					
CUBT5	basketry					
CUBT6	doors and windows					
CUBT7	shade house					
CUBT8	furniture					
CUBT9	mats					
CUBT10	rudimentary furniture					
CUBT11	household utensils					

	Contemporary use of bamboo	1	2	3	4	5
CUBM1	scaffolding					
CUBM2	bamboo mat board					
CUBM3	flattened bamboo boards					
CUBM4	bamboo jute composites					
CUBM5	ceiling					
CUBM6	construction frame					
CUBM7	foundation					
CUBM8	man-hole covers					
CUBM9	bamboo flooring					
CUBM10	plywood					
CUBM11	fiber board prefabricated houses					
CUBM12	particle board					

Thank you!

APPENDIX B

Photos record during field observation of bamboo house in Awi Zone



Figure 1: Recreational bamboo house (field observation)



a. Traditional bamboo house



b. Traditional bamboo wall and roof

Figure 2: Traditional bamboo house (field observation)

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Figure 3: Traditional bamboo window (field observation)

Bamboo based house and decoration

Houses decorations were practiced in Awi Zone are good in its aesthetic appearance especially on bamboo ceiling. But the technology of bamboo roofing, door, window and wall were not more exercised.



Figure 4: Improvised bamboo house (field observation)



Figure 5: Improved bamboo ceiling (field observation)



Figure 6: Improved bamboo wall (field observation)