CHALLENGES OF TECHNOLOGY TRANSFER IN CONSTRUCTION INDUSTRY: THE CASE OF PREFABRICATED ELEMENTS IN BUILDING CONSTRUCTION IN ADDIS ABABA CITY

MSc. THESIS

ASGELE KIDU GEBREHIWOT

HAWASSA UNIVERSITY, HAWASSA, ETHIOPIA

JUNE, 2021

CHALLENGES OF TECHNOLOGY TRANSFER IN CONSTRUCTION INDUSTRY: THE CASE OF PREFAB ELEMENTS IN BUILDING CONSTRUCTION IN ADDIS ABABA CITY

ASGELE KIDU GEBREHIWOT

A THESIS SUBMITED TO FACULTY OF CIVIL ENGINEERING AND BUILT

ENVIRONMENT, HAWASSA INSTITUTE OF TECHNOLOGY,SCHOOL OF

GRADUATE STUDIES,

HAWASSA UNIVERSITY,

HAWASSA, ETHIOPIA

IN PARTIAL FULIFILMENT OF THE REQUIREMENT FOR THE DEGREE OF MASTERS OF SCIENCE IN CONSTRUCTION TECHNOLOGY AND MANAGEMENT

JUNE, 2021

DECLARATION

I hereby declare that this masters of Science in Construction technology and management thesis is my original work and has not been presented for a degree in any other university, and all sources of material used for this thesis have been duly acknowledged.

Name: - Asgele Kidu

Signature: -------------------

This masters of Science in Construction technology and management thesis has been submitted for examination with my approval as thesis advisor.

Name: - Desalegn Girma (Ph.D.)

Signature: --------------------

Name: - Natnael Lejore (MSc.)

Signature: -----------------------

Hawassa University, Hawassa, June-2021

ADVISORS’ APPROVAL SHEET

SCHOOL OF GRADUATE STUDIES

HAWASSA UNIVERSITY ADVISORS’ APPROVAL SHEET

This is to certify that the thesis entitled “Challenges of technology transfer in construction industry: the case of prefab elements in building construction in Addis Ababa city” submitted in partial fulfillment of the requirements for the degree of Master's with specialization in “Construction Technology and Management”, the Graduate Program of the Department/School of Civil Engineering and Built Environment, and has been carried out by Asgele Kidu ID. No GPCoTMR/004/11, under our supervision. Therefore we recommend that the student has fulfilled the requirements and hence hereby can submit the thesis to the department.

Desalegn Girma (Ph.D.) ………………… …………………

Major Advisor Signature Date

Natinael Lejore (MSc.) ---------------------- -----------------------

Co-advisor Signature Date

………………… ……………..

School Head Signature Date

EXAMINER'S APPROVAL SHEET

SCHOOL OF GRADUATE STUDIES

HAWASSA UNIVERSITY EXAMINERS' APPROVAL SHEET

We, the undersigned, members of the Board of Examiners of the final thesis open defense by ASGELE KIDU have read and evaluated his thesis entitled "Challenges of technology transfer in construction industry: the case of prefab elements in building construction in Addis Ababa city", and examined the candidate. This is, therefore, to certify that the thesis has been accepted for partial fulfillment of the degree of master with specialization in Construction Technology and Management.

________________________	________________	____________
Name of Major Advisor	Signature	Date
________________________	________________	____________
Name of Internal Examiner-I	Signature	Date
________________________	________________	____________
Name of Internal Examiner-II	Signature	Date
________________________	________________	____________
Name of External examiner	Signature	Date
________________________	________________	____________
SGS Approval	Signature	Date

ACKNOWLEDGMENT

This research study would have been impossible without the support and assistance of a number of people who have showed me their kindness and generosity.

First, I would like to thank the Lord for all that He has done for me in my life, and creating all the conditions needed for the fruition of this research. Next, I would like to take this opportunity to express my deepest gratitude to my supervisor, Desalegn Girma (PhD.), for his invaluable guidance, patience and encouragement throughout the preparation of this thesis. At the same time I would like to thanks Natnael Lejore (MSc.) for his following up on my progress and providing me encouragement and support.

Secondly, I would like to thank the ERA program for sponsoring me. As well as I would like to thank the people and organizations that contributed to the questionnaires and interviews, offering their precious time and providing much valuable information from the construction industry in Ethiopia to assist in the completion of this research.

Last but not least I would like to thank my families and friends, for their patience, sacrifice and encouragement. Without the support of my family and friends, this thesis would not have been completed.

TABLE OF CONTENTS

LISTS OF FIGURES

LIST OF TABLES

ACRONOMYM

BCWS	Building Construction Works Sector
CID	Construction Industry Development
CI	Construction Industry
CTT	Construction Technology Transfer
DCMME	Defense Construction Materials Production Enterprise
EASE	East Africa Specialized Engineering
ECWC	Ethiopian Construction Works Corporation
EiABC	Ethiopian institution of Architecture and Building Constructions
Ft.	Feet
IMS	Integrated Modular System
MSE	Micro and Small Enterprise
PBPPE	Prefabricated Building Parts Production Enterprises
R&D	Research and Development
RII	Relative Importance Index
SICU	Sustainable Incremental Construction Units
SPSS	Statistical Package for Social Science
TT	Technology Transfer
WWII	Second World War

ABSTRACT

Many construction innovations incorporate technologies that have been transferred from one geographical area or discipline to another for the facing numerous difficulties in the industry. Technology Transfer (TT) is in the interest of many developing countries; however it is not pacing forward as its target. Many of developing countries set policy to transfer prefabricated construction technique, yet there was a problem on its succeeding. Technology transfer initiatives can be instrumental in solving a lot of challenges in building construction. Dynamic change is needed today to overcome new challenges in the construction industry. Adoption of prefabrication is one of the possible solutions to such problems. This paper assessed the challenges of transferring and expansion of prefabricated building construction techniques through both qualitative and quantitative research method. Besides, this study aims to evaluate the current status of prefabrication building transferring and adoption in Ethiopia and, identified the best channels of transferring and expanding the technology. An extensive literature review was conducted on this subject towards the understanding of TT and prefabricated building construction in developing countries. And, a set of questionnaire and semi-structured interview was used to collect the data. As well as two case studies was conducted. Mean index and RII method using SPSS, and Excel has been used to analyze the results. On this study the practice of prefabricated building technology in Ethiopia shows almost to non-existence. As numerous challenging factors are impeding the adoption, and development of prefabricated technology in developing countries. The result shows, limited awareness and trust on the technology and shortage of initial funds are the most challenging factors in transferring and expanding of prefabricated building technology in Ethiopia. Shortage of infrastructure is also one of the critical obstacle in expanding the technology. Furthermore, as the succeeding of adopting and developing of one technology was measure through the mechanism used to adapt and improve the technology. Hence the study shows trainings was the best way to transfer and sustain prefabricated technology. As well as sub-contracting was the second best way in transferring and sustaining the technology. Other critical channel to improve the technology was working in research and development.

Keywords: Building, Challenges, Construction, Ethiopia, Prefabricated, Technology Transferring,

1 INTRODUCTION

1.1. Background to the Study

Construction Industry Development (CID) was measured based on considerate process used to improve the capability and success of construction industry, technological advances in order to meet the demand for building and other civil engineering works, and to support sustained national economic and social development objectives (CIB, 1999). Beside to, construction industry development was defined as ‘the deliberate and managed process to improve the capacity and effectiveness of the construction industry to meet the national economic demand for building and civil engineering products, and to support sustained national economic and social development objectives(Matsumura, et. al., 2019; Ofori, 2015). This development was determined by many factors, as Ofori (2015) identified eight factors for CID in developing countries; those are: economic growth and stability, government recognition, planning and resources utilization, codes and procedures, use of local materials, education and training, appropriate technologies and incentives for local contractors. In developing countries like Ethiopia CID was facing a lot of problems like, use of outdated technologies, poor productivity and the dominant rent seeking behavior that curtails innovative competition (Tsedeke, 2017). Research on construction industry development and the effort to implement its findings have broad aim of solving the problems facing the construction industries of developing countries (Hiwot, 2012).

Construction Industry (CI) as whole not only includes the assembly and design activities, but also the manufacture and supplies of the components and materials that go into building and engineering construction projects and the manufacture and supply of the equipment used on these projects. Construction industry require continuous development, to enhance the three parameter of construction performance indicators “time, cost and quality". On the developed countries there are a lot of construction system have been invented and adopted. One of construction system appeared in this time was prefabrication , and spreading throughout the world (Dave, et al., 2017). Developing countries also trying to transfer and adopt the invented technologies on the construction industry to overcome the shortages of technology in their construction industry(Uusitalo & Lavikka, 2020). Technology Transfer (TT) can be widely considered as a potentially powerful source of innovation which can provide construction firms with new technologies that can appropriately transform and complement current technologies to create and sustain enhanced levels of performance (Barrett, 2004). (Carrillo, 2006) Defined as TT "the process whereby knowledge in some form is transferred from a person or organization who possesses it (the transferor) to another person or organization who arranges to receive it (the transferee)". TT process should go beyond the implementation of a single project and ensure that transferred technologies and skills are continuously applicable thereafter and are internalized with the local firms. Some agreement shows the succession of technology transfer measures by its absorption and diffuses to the recipient organization or country. Now a day, prefabricated construction has become one of the major mechanisms of the developed countries construction technique and almost 100 percent of building construction utilizes prefabricated materials and prefabrication construction methods (Omid et al., 2016).

For years, in Ethiopia there has been commitments by the Ethiopian government to improve local productivity, especially in construction and manufacturing industries through the integration of foreign technologies into the country's manpower(Gatew, 2011). However there was a limited capability in performing new technologies like prefabrication construction method(Jakele, 2017). In Ethiopian CI prefabrication is still not familiar. Because those developing countries like Ethiopia have different social and economic systems from those developed one, they tend to use more actual manpower for constructions rather than prefabrication methods. Construction methods that require a lot of physical labor such as masonry, hand paint or cast-in-place concrete are common in Ethiopia(Tesema, 2019).

In Ethiopia the transferring of prefabrication of building construction materials elements was started already before four decades by adopting from former Yugoslavia to overcome the shortage of housing in Addis Ababa, Prefab Housing Factory for prefabrication is established in 1987G.C. Factory was organized administratively under the former Ethiopian Building Construction Authority. But its development is limited and not adopted well as the required (Gutema 1998). Currently also magnesium board and agro stone production factories are installed in different region of the country to produce building elements from indigenous materials. The role of prefabrication is for its potential to increase productivity and efficiency without compromising the quality of the product, and also it's faster and better construction technique (K. Chauhan et al., 2019). Hence for the continuous improvement of CID it is important to assess the barriers and capability of technology transferring in the industry. This study will focus on the challenges of TT in prefabricated building construction in its limited spreading out.

1.2. Problem Statement

Many studies shows technology transferring is a backbone of a nation economy development(El-Abidi, et al. , 2014; Jakele, 2017; Ofori, 2006). One of the main ways in national economy improvement is the involvement in construction sector (Auti, & Patil, 2019). However, the step to fit in new technologies in the construction industry was currently too slow to achieve today's life standards particularly in developing countries , mainly because of poor construction techniques, using outdated technology, poor utilization of resources and poor overall management(Jakele, 2017; Ofori, 2015). In Ethiopia the national capability to learn, adapt and withstand new technology was still at a very low stage in all sector (Kassu, 2012).

As technology transferring is a backbone of one country effectively adoption and sustenance of the transferred technology was key measurement to the success of the technology(Mulu, 2018). Many developing countries has lack of prefabrication technologies but have proposed several policies for mechanization or prefabrication in their respective construction industries(El-Abidi et al., 2014). Ethiopia has attempted the transfer of various modern and noticeable technologies, since the era of Emperor Menilik II (1886-1930) (Gatew, 2011). According to Tessera one of the technology that was transferred from other countries in Ethiopia, but not well adopted and not meet the target was prefabricated building technology(Tessera, 2020). Lack of proper technology transfer and sustaining it were the main challenges of using prefabrication technology in Ethiopia (Legese, 2020).

The experiences (Chane, 2017) in Ethiopia in transferring and adoption of prefabrication technology in the provision of the housing was before almost Four decades by the prefabricated building parts production enterprises (PBPPE), now included in Ethiopian construction works corporations. There is very little application for some few of prefabrication building construction in Ethiopia to solve problems in shortage of housing across the country(Ali, 2009). Nerveless the development and spreading out across the country was limited and it couldn't saturate to the sector(Tessera, 2020). As government and private sector stake holders in construction industry are not well worked with prefabricated building systems(Geleta, 2019). Although, technology transfer is not far from a ''one-step shopping''(Girma, 2020). This indicates that our capacity of receiving and sustaining technology is still undeveloped and needs further attempt(Chane, 2017).

1.3. Research Questions

The following research questions were drawn from the problem statement:

- What is the level of ttransferring, development and practice of prefabricated building technology in Addis Ababa building construction?
- What are the challenges of technology transfer in construction industry considering the case of prefabricated elements in building construction?
- What are the mechanisms to effectively diffuse the technology in the industry and ensure its sustenance?

1.4. Objectives

1.4.1. General Objective

The main objective of this study is to assess the challenges of technology transfer and its adoption in construction industry focusing on the case of prefabricated building elements in Addis Ababa city.

1.4.2. Specific Objectives

- To assess technology transfer practice in Construction Industry considering prefabricated building elements in Addis Ababa construction industry:
- To identify the challenge in transferring and ensuring sustenance of prefabricated building elements in Addis Ababa construction industry.
- To identify effective technology transfer mechanisms of prefabricated building construction.

1.5. Significance of the research

Saving time, money and improving the quality in construction field even in ordinary project is part of the heart of the industry development, this research show challenges of transferring prefabrication technology in building construction. As transferring the technology helps in solving the shortage of housing, save time and decrease cost with suitable mass production even with high initial costs, it is good solution for building with big mass production when the demand of housing is very high like Ethiopia. Therefore the output of the study will be an input to construction industry stakeholders how to look the existing potential of transferring and expansion of prefabricated technology, and it is also important for being a reference for further studies in the industry. This research is significant in that it may help the people engaged in the construction industry how they can transfer prefabricated technology in building construction, and help them in identifying the impediment of its adoption and development.

1.6. Scope and Limitation of the study

Since the prefabricated building construction was practiced before a long period of time, but its development was lagged behind; in the process, the research investigates the current state of prefabricated technology transferring in Addis Ababa city, and also the study focus on challenges of technology transfer in prefabricated building construction and mainly it's limitation to adopt and saturate it to the industry, and effective mechanisms of transferring the technology was assessed in this study. The research scope and the population for data collection is limited to construction organizations and academicians in Addis Ababa city only.

Apart from the time and financial constraints, the researcher encountered some limitations that could negatively influence the undertaking of the study, some of them are: - simple random sampling was used to collect data this may affect the result of this, if the selected participant was had limited knowledge on the topic. Also the current pandemic COVID-19 was another challenge to interacting and discussing with people.

2. LITERATURE REVIEW

2.1. Introduction

Traditionally, construction industry lags behind in terms of technology and skills compared to other industries, although the extent to which the industry lags behind differs substantially between developed and developing countries(Ofori, 2015). Before pacing to the TT knowing the concept of technology is very crucial; the definition of technology may vary in in different fields. As cited in (Osabutey et. al. 2014) the Grosse definition of technology was more emphasizes the integration of knowledge and product on technology. In the construction industry; construction technology may be viewed as having both hard elements (construction outputs, materials, plant and equipment product technology); and soft elements (skills, knowledge, organization management technology) and the integration of those two technology can see as process technology includes techniques and method to produce a construction output (Elmer & Meltofte, 2012). According to (Jakele, 2017) construction can be defined as the development (conceptualization, programming, planning, designing, execution, operation and maintenance, and demolishing) of physical structure. Wubshet also define technology as a method/technique, process and/or inputs use to enhance the performance of your job in terms of time reduction, cost minimization, waste reduction, and safer way, easier to do, stronger and totally performing you work in effective and efficient way. Based on the above definition CT can be defined as the application of best way for the completion of your project(Jakele, 2017).

Technology transfer (TT) was defined in various ways by different scholars and institutions: TT refers to the transfer of the components of technology from one economic agent to another. Simplified definition for TT may the diffusion of technology as well as the dispersion of know-how and skills(Mulu, 2018). (Kassu, 2012) on his report on the Ethiopian science technology and innovation policy issue technology transfer was primarily focus on devising a system of learning, adapting and utilizing as well as disposing of imported technologies in order to meet national demand.

Based on the above definitions; TT is main instrument in developing infrastructures in developing countries. Infrastructure projects in developing countries include hospitals, highways, dams, harbors, airports, and water processing facilities, power plants and, oil and gas processing plants, and other high rise buildings projects are passing through a technical process and require know-how to implement them. But local contractors in developing countries have lack in technology needed to undertake the usually large and complex construction infrastructure projects (Ofori, 2015). Most of the time contractors from developed countries are able to compete and win most of these projects through international tendering, because they have the requisite technology (Osabutey, 2014). In this overview the important of TT for the development of the construction industry as well as for the nation economies is predefined.

One of the infrastructure projects in construction was building constructions. Building constructions includes housing projects, industrial buildings, institutional and others. Housing is one of the basic necessities for human beings. Experts and scholar suggested transferring and adopting prefabricated building construction technology which help to develop the living standard of community(Navaratnam, et. al. 2019; Osabutey et al., 2014). Experiences from advanced countries in case of prefabricated building system (i.e., pre-cut, panelized, modular, and mobile home building system) and constructions technologies indicate that there is a potential advantage to improve building construction performance in the aspect of cost, speed, and quality of building construction. Through the above advantages of countries tried to adopt prefabricated building construction systems utilization helps to address a wide range of problems in housing and building. However, its effectiveness is lays in question due to a lot of challenges. In all around the world prefabrication technology was adopted from Europe and standardized according to local conditions. For the purpose of this study technology transfer can be defined as "the process by which technology, knowledge, and/or information developed in one organization, one area, or for one purpose is applied and utilized in another organization, in another area, or for other purpose"(Ofori, 2006).

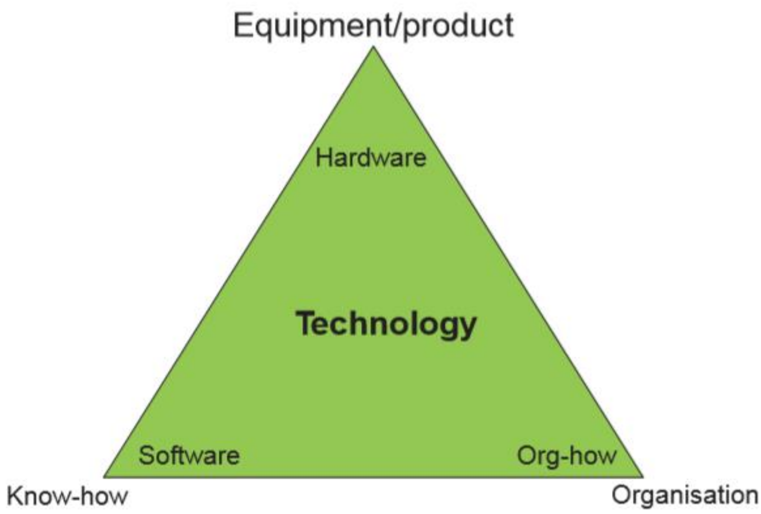

Figure 2.1 Elements of technology (Osabutey et al., 2014)

2.2. Technology transfer in Ethiopia

In most of African countries modern science and technology was introduced during the colonization period. In case, in Ethiopia the beginning of modern science and technology was during the first half twenty century with the establishment of higher institutions(Gatew, 2011). In this sense, Ethiopia has attempted the transfer of various modern and noticeable technologies, since the era of Emperor Menilik II (1886-1930). Some of the major technologies have been acquired in the form of turnkey in construction projects, international technology co-operation, and recently through Foreign Direct Investment (FDI), Joint Ventures (JV), and via the local businessmen. However, technology transfer is not far from a ‘’one-step shopping’’ of technological hardware. Hence, most of the technologies imported to Ethiopia with limited resources have failed to be adopted, improved, re-engineered, and disseminated to other similar industries at the desired level, which should be considered as the ultimate goals of technology transfer(Tesema, 2019).

These results, in the lack of self-capability to undertake major infrastructure development activities like, road and building construction, bridges, hydropower dams, sugar industries, and cement industries etc. by the citizens of the country. This clearly indicates weakness in absorbing foreign technology from similar projects and industries which took place several decades ago. Technology acquisition is theoretically defined as the generation of missing technological and managerial competence within companies in developing countries and the reduction of their long-term dependence on foreign capital, skills, and technology transfer of physical production facilities, human skills and resources, operating procedures, and managerial structures as essential factors in the acquisition of technology In the case of construction industries there is a lacks national technology transfer coordination and implementation strategy to build the capacity of the construction sectors through technology transfer from both foreign and domestic sources(Jakele, 2017; Mulu, 2018).

2.3. Purpose of technology transferring and technological development in construction industry

As defined above, technology transfer has great role in economic transition of a nation and on its technological improvement, nevertheless primarily to developing countries, is often unsuccessful (Kebede & Mulder, 2008). Different scholars and institutions were describe different purpose of technology transferring such as (Jakele, 2017; Ofori & Ofori, 2006; Transfer

& Planning, 2016) states the main purpose of technology transferring was to link the gap in advance technologies experienced in developing economies, improve competitive advantage of company, pivotal to advancing both society and social welfare(Uusitalo & Lavikka, 2020), growth of local industrial capacity of a nation; in relation to construction industry (Devapriya & Ganesan, 2002), states the purpose of technology transferring in construction industry to improve productivity and technological capability for any construction work. However there has not been clear harmony of what TT should aim at, and how it can be successfully achieved in the construction industry of DCs (Simkoko, 1989). Wubshet ("1st Construction Profession Week Magazine" 2017) states also benefit of technology transferring as improved efficiency/productivity and effectiveness, improved products quality, improved profit, learning by doing, diversification of new product and markets, improved technical and managerial capabilities, and social, environmental and economic advancement (import substitution) of the transferee(Jakele, 2017). TT helps in achieving three main objectives: the introduction of new technology, the improvement of existing techniques, and the creation of further knowledge(Shukra, et. al. 2021). In past few decades has motivated the construction industry to look for and adopt new technology to overcome the challenges associated with the development of buildings and other infrastructures. Firms are increasingly focusing on the area of design like application of BIM technology, an area of construction such as prefabrication which has hugely increased efficiency. The main aim of technology transfer in construction industry is to effect technological development in the industry(Theodore, et. al, 2014; and Ofori, 2006).

Technology transfer in construction industry can described as (1) movement based vertical movement from the source to its destination (from universities and research & development to the construction industries; and from developed countries to developing countries) and the other one is horizontal movement which is from one place to another place, from one organization to another organization from one country to another country, and from one individual to another individual; (2) based on responsibility sharing technology transferring can described as transferee-transferor responsibility sharing in this dimension when capacity, willingness, contracted/commercialized, confidentially, protecting competencies and TT experience was needed from the source; and readiness, demand and priority, technology acceptance conducive environment commitment to use/apply and absorptive capacity are needed from the destination part respectively. (3) technology transfer can view as transferring knowledge and skills through product, service and work based (Jakele, 2017).

In general, TT should be perceived in terms of its potential contribution to socio-economic development, infrastructure development, industrialization and construction industry development. This indicates that a contribution to expanding construction capacity and capability was being a common goal in all TT activities. In practice, TT may involve both low technology and high technology initiative. Therefore, technology transfer to developing countries entails a substantial increase in production capacity and, most typically, enables the achievement of economies(Adindu, 2020)..

2.4. Technology transfer process

In technology transferring there are phases or steps involved on its application. First, putting a boundary on ‘‘the technology’’ which will to transfer. Second, outlining the technology transfer process according to its purpose local capacity of the hosting organization or nation. Third, measuring the impacts of transferred technology challenges scholars and evaluators, requiring them to reach deep down into their research technique kit bag. Diffusion of the developed countries’ technologies to the developing countries plays an important role in meeting the technological needs of these countries. However in most of developing countries adopting, improving and spreading out transferred new technology was very low accomplished. Diffusion also occurs through technology transfer(Ray, 2012). The following are four steps involved in technology transferring and diffusion stated by (Bakar & Tufail, 2012).

1. **Technology acquisition**

This phase was includes technology selecting and managing from foreign countries or from one organization to the other. Studies shows Ethiopia has good practice in technology selection for specific purpose but the trouble here According to Bakar and Tufail, 2012 this phase involved various activities in technology acquisition are stated below.

a) Selection of technology: the selection of technology should base on factors like appropriateness of the technology, cost-effectiveness of the technology, and possibilities of updating, environmental friendly and proven utility of technology.
b) Selection of collaborators: there are many considerations involved on selection of collaborators including preparation of notice inviting tender, issue of international tender, negotiation, and final selection.

c) Finalization of agreement: this is an agreement which is reached with the party and finally selected at the required price and terms and conditions settled through contract or negotiation.

2. **Technology absorption**

On the absorption stage activities are involved. Those are preparation of detailed project report, interrelation of various rights and obligations of the agreement by both parties (i.e. receiver and collaborator), project implementation as pre-established (within allocated time and cost), and periodic evaluation of the technology.

3. **Technology adaption**

If the technology is acquired and absorbed successfully the next stage is to integrate the same with production infrastructure and social environment of industry which receive the technology. Integration requires (1) indigenization of components and subscription (2) vender development (30) acceleration and (4) co-ordination and co-operation. This stage was successful if it applied properly imported technologies only after adapting them to fit local surroundings(Ofori, 2006).

4. **Technology improvement**

The last stage of technology transferring is technology improvement and it depends on the continuous application with ongoing research and development process. The same to that according to Mulu, (2018) TT can implement through a connected stepes develop a model which uses as good guide for selecting strategies or polices for the adopting the technology. In this stage aimed at screening alternative technologies, contain physical and research and development activities, final development and implementation of the technology.

2.5. Prefabrication technology

The history of prefabricated building shows, in 1624, there was a panelized wood house constructed in England and transported to Massachusetts for the accommodation of a fishing fleet. This was the earliest known prefabricated home(Smith, 2009). Until the Industrial Revolution, there was very little activity, as there was no need for prefabricated homes. Without the benefits of mass production, prefabrication was not cost efficient. Developments in the prefabrication industry was because of breakthroughs in mass production due to the growing need of transportable settlement camps and housing caused by England’s colonization frenzy. The reason countries transferred and adopted prefabricated technology includes housing problem at the upfront and quality, time, sustainability and other construction performances (Smith, 2009).

2.5.1. Prefabricated Building Definitions, Categories and Concepts

As it is shown by different literature, Prefabrication is the practice of assembling components of a structure in a factory or other manufacturing site and transporting complete assembles to the construction site where the structure is to be located. Prefabrication technology aims at creating an accelerated method of construction where a building is constructed in parts that are prefabricated off site in well-equipped manufacturing facilities under controlled environment. There are two main systems to consider in prefabrication, the design and the construction. These are tangentially more interrelated than in a so-called ‘traditional’ method. In a prefabrication model, it is normal for the design system to take longer than in a traditional way, and the main gains are expectedly obtained in the construction stage. The prefabrication process includes finalization of design of various components of structure, casting and curing of units, transportation of units on site and installation of these units. The prefabricated units may be whole or they may be parts of larger spaces which are combined together to form complete components. The term prefabrication can apply to any construction method where a significant part of the construction takes place off-site in a factory that produces relatively large, complex pieces that are then assembled at the site into the finished building(Auti, & Patil, 2019; Smith, 2009). Most of the time prefabricated construction is a new technique and is desirable for large scale housing programme.

(Goodier, 2007; El-abidi & Ghazalia, 2015) stated that prefabricated building can be generally classified into five levels according to the prefabrication degree applied on the product. However, to clarify classification, the original term “pre work method,” which consists of “prefabrication,” “preassembly,” and “modularization,” should be initially defined.

Prefabrication is any component manufactured off-site, which is not considered as a complete system to be prefabricated. This is categorized as Zero-level “Basic Material” without pre installation assembly features(Goodier, 2007). . In practice, “prefabrication” means “the manufacture of component parts of a building and its services prior to their assembly on site”(Auti, & Patil, 2019).

Preassembly means “the manufacture and assembly of a complex unit comprising several components prior to the unit’s installation onsite” (Make = Fabricate + Assemble). It is generally regarded as a combination of prefabrication and modularization(Polat, 2010).

Modularization generally refers to pre constructing a complete system in a location away from that on the job site, and then transporting the completed system to the site(Dimitrijevic & Jovancov, 2000). According to (Shen et al., 2017), modular systems are generally similar to hybrid systems; however, they typically consist of multiple rooms with 3D units. Modular systems can be complete factory-built houses or apartment blocks, which are constructed and preassembled. Trim work, as well as electrical, mechanical, and plumbing fixtures, is also installed.

Off-site Construction includes preassembly, hybrid building systems, panelized building systems, and modular building systems(Mostafa et al., 2014). Meanwhile, the term off-site manufacturing covers different categories of factory manufacturing of buildings; these categories include off-site fabrication, off-site assembly, off-site construction, and off-site production(Hong, et al., 2018).

Industrialization describes all pre work forms (prefabrication, preassembly and modularization), which relatively implies the use of fully integrated and automated project processes. (Tam & Tam, 2015) stated that industrialized building systems refer to the complete integration of all subsystems and components into a general process that fully applies industrialized production, transportation, and assembly techniques.

2.5.2. Advantages of prefabrication for the construction industry

Where prefabrication is possible, a number of benefits make these systems attractive to building owners. Prefabricated building can help resolve environmental issues as well as improve the flexibility of construction designs. Several studies have also cited numerous benefits of prefabrication technology in the construction industry(El-Abidi et al., 2014). Prefabricated systems can lead to reduced labor costs, safer projects, and fewer delays, and often results in an overall higher quality product than can be achieved with traditional stick-built projects. Related to this, the benefits are driving enormous interest in prefabrication as a tool for streamlining construction and saving companies’ money. Stakeholders, contractors, managers and laborers all face simpler work timelines and requirements, driving further innovation in the field.

According to (Auti, & Patil, 2019; Jaillon & Poon, 2007; Taffese, 2012) the main advantages of prefabricated construction was listed below.

- Reduced labor costs by reducing the number of both skilled and unskilled labors
- Improved safety and security by shortening the amount of time on site and by creating factory controlled environment
- Minimized delays
- Improved quality finished project as it is completed in a specialized, centralized factory.
- Lower environmental impact by reducing pollution and disturbance of jobsites and quantified usage of resources
- Waste minimization.
- In both developed and developing countries prefabricated technology was applicable to solve housing shortage, by producing prefab elements in mass according to the standards of buildings.

Factors	Prefabrication	On-site
quality	Supports tentative weather climates and can give expected results	Tentative weather climates does not give out expected results
speed	Speedy process (up to 70% less)	This type consumes more time may due to weather conditions
cost	Reduced cost due to greater control over manufacturing results	Scheduling and weather may increase the construction cost
versality	Less	More
site refuse	Less waste	A large amount of waste is produced which also lead to additional cost

Figure 2.2 Summary of Prefabrication Advantages over on-site construction(Nadu, 2016)

2.6. Practice on prefabrication technology transferring and development

"The first prefabricated building was built in the 1600' in England and was shipped to Massachusetts" (Baghchesaraei et al. , 2015). However it become popular in many countries after WWII due to a lot of military personnel returned to their countries and forced builders to build faster. Some builders made off-site building components then delivered them to other builders or home buyers rather than building everything at the site.

The prefabrication knowledge was started to import to different countries during 1950's. Designers and contractors tried to identify a specific schematic design for prefabricated buildings market, since the suitability of different kinds of construction methods to promote their knowledge and product to make ready for the market. And different countries used to solve their corresponding problems (e.g. most African countries try to solve their shortage of affordable housing, Hong Kong to solve shortage of local labor, USA and Japan to solve shortage of housing due to war etc.). As time goes on in the last decades, different difficulties arose in construction issues and in many developed countries the governments chose prefabricated buildings as one of their solutions in construction (Hui, 2015).

Lack of knowledge and experience has caused reducing in use of prefabrication construction technologies in many developing countries, but through a time the knowledge and technology of prefabrication was imported from developed countries to developing countries. Now a day prefabrication technologies play an important role in multiple developing countries and its usage has been increasing every day(Reza et al, , 2016). Practices in developed countries in the case of prefabricated building systems and constructions technologies indicate that there is a potential advantage to improve building construction performance in the aspect of cost, speed, and quality of building construction. On the other side the adoption of prefabricated technology was not achieved its target in developing countries and limitations on its expansion in all parts of their country (Baghchesaraei et. al., 2016; Geleta, 2019).

2.6.1. Prefab technology transfer practice in some selected countries

The following good practice of transferring and diffusing of prefabricated technology was discussed below.

- **Japanese experience**

In Japan also start manufactured housing around 1950s and 1960s, due to WWII, lots of houses were destroyed during this war. After the war needed residential house is urgent to recover from urban destruction. To overcome those high demands in housing prefabricated technology was adapted from European countries. According to (Manley, 2019) during the first time of adaptation there was a problem in shortage of local materials and awareness on the technology. However, the Japanese government established architectural institute and conduct researches on And more houses were constructed without sacrificing the quality, cost and waste of the building using the "prefabricated housing" technology(Matsumura et al., 2019).

According (Correia & Murtinho, 2012)the Japanese approach for prefabricated building construction has the following main aspects: the market structure and attention to customer choice; the nature of housing as a product; the dominance of new build and absence of a developed market in second-hand houses; a distinct framework for innovation formed by government and industry, including regulations, and public and private investment in research and development focusing on production methods and customer requirements; the concept of industrialization as a means to customer choice, to maintenance of built quality, and to flexibility of site operations, rather than simply a means to reduce unit costs; a strong commitment to developing electronic data models of building processes and buildings as products in use, which could lead to the integration of digital data and its access by a wide range of participants; a willingness to exchange ideas to help develop the sector as a whole. In Asia, Japan is a pioneer in prefabrication, using timber, metal, fiber glass and plastics as the main building materials.

Japan also invents their own construction techniques and conducts their own research, which is suitable for their economies, geographies and populations. Now a day Japan has its own industrial standard for prefabricated housing, which is different from the USA and Britain(Matsumura et al., 2019). It is said that a house is made by prefabricated housing if the two third or more construction process is finished in factory and the main parts of house, such as walls and floors, are pre-made following certain industry standards (Matsumura et al., 2019)

- **China experience**

Formerly the prefabricated building construction in china was known as Industrialized Building (IB) which is imported from United Kingdom to construct Bank in Hong Kong(Smith, 2009). It is agreed through many research that IB have a key role in the Chinese residential development due to its benefits in improving quality, productivity, cost- effectiveness, safety and sustainability, and be of great scientific and engineering significance to transformation and upgrade of the construction industry (Zhang et al. 2014, Han and Zhu, 2017)). However, lack of understanding the potential benefits on prefabricated house limited the acceptance of prefabricated houses. During the first development of Chinese prefabricated construction there were absence of regulations and incentives, and high initial costs. Lack of manufacturing capability, product quality problems and lack of supply chain to the market are the key challenges of the prefabrication technology development in China were persistently mentioned previously. Avoiding of these challenges would help in fundamental development for local construction sectors for future implementation of prefabrication(Wang, et. al., 2019). To give a definitive solution to the impediments the Chinese government trying train their work force, establish standards and manual guide for the method, a lot studies are done on their research institutions(Shukra et al., 2021).

The chines government promote prefabricated At present, most of the prefabrication methods are used on structural components, such as precast façade, structured wall and column, semi-precast slab, staircase and refuse chute. Now china was the one which use prefabricated technology highly.

- **Malaysia experience**

Firstly, prefabrication construction in Malaysia was imported from former Yugoslavia Europe country, and the development is not enough as required. But currently the research found that the prefabricated house building in Malaysia has reached market maturity and well adopted currently. The Malaysia Government has adopted the Industrialized Building Systems (IBS) in the housing projects to improve delivery timing, and producing affordable and quality houses (CIDB 2012). Besides adopting IBS, the government has well established IBS legislation and building codes to enhance the uptake of high quality prefabricated houses for the construction sector. Nevertheless, supply chain integration was urged to maintain the competency of future house building supply (Azman et al. 2010). Currently in Malaysia, “the National Council for Local Government” mandated the private sector to construct prefabricated building for housing projects amounting at least 50 million to attain the minimum prefabricated building score of 50 by 2020.

Malaysia was working with Japans Company called (Daiwa Prototype House Builder) to build 100 units of prefabricated building to overcome shortage of homes as well as to construct in short period of time. A steel framed structure was covered with heat insulators before attaching gypsum boards buildings was constructed with only two months roofs were supported with mild steel which is heavier than conventional steel, then covered with cement boards with rod wool underneath for heat and sound insulation. It was uncommon for buildings in Malaysia to incorporate heavier roof structures, as typhoons do not occur in Malaysia. Walls were incredibly straight as they are all precast concrete, which works efficiently for fast paced construction. Steel bracings supported thicker walls in order to withstand strong wind and earthquakes in Japan. Such structural support was implemented in the creation of this prototype unit(El-Abidi et al., 2019).

- **Ghana experience**

The government of Ghana was signed agreement with Soviet Union during 1962 for the establishment of a factory to produce large-span precast concrete elements for the construction of houses(Osabutey et al., 2014). The design of this precast concrete was imported from Soviet Union and modified to Ghana local condition and the construction of prefabricated houses was completed by Ghana national construction corporation. The buildings had been completed in 1966 and the equipment installed, but the factory was not able to commence production as the new military regime suspended the project. After rehabilitation the factory started producing houses in 1978 with the slogan "Own your house in 30 days". But the factory not capable in fulfilling the demand of applicants due to the shortage of skilled personnel; because only transferred the design and shortage of trained personnel’s (Ofori, 1990). They highlighted the core prefabrication uptake barriers in Ghana including unwillingness to innovate, scarcity of codes and standards, supply chain integrations, and well-skilled manpower requirements. To address these barriers, governmental support is a pivotal in helping to establish prefabrication building construction as a viable alternative to traditional approaches. Beside this the Ghanaian technical and vocational education centers linked with the foreign construction company in internship to get experiences(Essienyi, 2011). In Ghana there are a lot of foreign contractors used prefabrication building techniques there reason to awarded contracts such alike projects was the shortage of technical capability in local contractors. From those housing company Red Sea Housing Company PNG Ltd. Was participating in prefabricated building construction. However a large number of small and medium-sized construction firms exist, but they generally lack the key capabilities required to be awarded major contracts(Osabutey & Jackson, 2019). Currently the Ghanaian national housing policy decided to participate foreign company to invest in housing construction. This may help in transferring technology to the local contractors and workers.

- **Yugoslavia experience**

In Yugoslavia 1911 to 1931 was the age of experimentation in the housing industry. Architects such as Frank Lloyd Wright and Walter Gropius experimented with prefabrication as a method of reducing labor cost and solving housing shortage problems. The prefabricated building construction was adopted from United Kingdom and designed the Usonian House using the grid system – a system that allows repetition of details and dimensions. Between 1930 and 1945, the prefabrication industry experienced its second growth. The reason of this growth was due the poor economy and people's desire for a more affordable home during the depression and war. Yugoslavia construction industry was started development of prefabrication technologies during post WW2. Due to the bad economic conditions resulting from the war damage and undeveloped pre-war social condition, Yugoslavia was faced with a number of serious problems in building, (i.e. Reconstruction of the country, Establishment of new industries, and Housing) (Vukov, 2013). After that, for the purpose of recovery and industrialization, especially in the case of housing, civil and industrial infrastructures and public facilities by using different path from European and globe context. During that time Yugoslavia's building technology was undeveloped and the legislation was unclear and outdated. Therefore Yugoslavia government takes step to redevelop design and construction technologies to produce construction materials and other industrialized process of building construction to overcome the above shortages(Kulić, 2012).

Table 2-1 summary of review on other countries prefabrication adoption and development

Country	The pushing factors to uptake prefabrication	Challenges	Solution	References
Europe (UK)	• Solving shortage of housing distracted by WWII in short period of time • Colonization expansion • The energy efficiency and sustainability agenda • To enable future construction to be: flexible, agile, value driven, knowledge-based, highly customer centric, efficient and comparative • The economic factors-reducing cost	• High initial cost and market strategy • Connection problems • Shortage of skills	• Mass building • Provide standards and guidelines • Improve the overall practices • Collaborative projects with industries and academicians • Promoting the technology • Financing for research on prefabricated technology	(Smith, 2009), (Goodier, 2007)
USA	• The housing shortage distracted by WWII in short period of time • To minimize on site operation • To improve industry's performance	• Inadequate feasibility study • Initial capital costs not predicted • high initial cost	• Establishment of precast institution • creating awareness on products using regular magazines	(El-abidi & Ghazalia, 2015; Ngoenchuklin, 2014; Polat, 2010)

	• Balancing tool in affordability of houses for high income and low income	• Confusion about how the building code is applied on prefabricated projects	• set standards for modular homes • open research and design/build/evaluate initiative centers focused on prefabricated building constructions	
Japan	• To fix housing problem Due to WWII • To reduce waste and time of construction • Recently to protect earthquake and CO_2 emission • To minimize on site operation	• First there was shortage of awareness on users • Materials are imported from USA and Europe during the introductory time	• Invent their own construction techniques and conduct their own research, which is suitable for their economies, geographies and populations • Market structure • Localization the construction materials • Collaborate with other sector (example with Toyota)	(Manley, 2019; Neilson, 2011; Smith, 2009; Yashiro, 2001)

China	• Overcoming housing shortage due to population growth • Solution for sustain construction and waste reduction • To improve the performance of construction industry	• Limited skills and knowledge in project delivery and supply chain, • Perception of clients and professionals, and • Lack of government incentives, directives and promotion	• Train their work force • Establish standards and manual guide for the method • Doing a lot of researches • Innovate and upgrading prefab systems	(Han & Zhu, 2017; Shen et al., 2017; Talmazan, 2020)
Malaysia	• To overcome shortage of local laborers • To improve quality and enhance productivity • producing affordable and quality houses	• Low acceptance of the method on the society • High initial cost make difficult to spread across the country •	• Collaborated with Japanese company • Established IBS legislation and codes	(El-Abidi et al., 2014; El-abidi et al., 2019)
Yugoslavia	• To solve Housing problem in the country • Demand for standardized homes	• Shortage of expertise during the starting • Shortage of initial funds to establish factory	• Establish their own systems called IMS • Adopting housing regulations • Upgrade the system using research study • Conducted Housing research	(Kulić, 2012; R.Dimitrijevic,. & S. Jovancov, 2000)

South Africa	• Solve housing problem • To minimize waste and time in construction	• Lack of industry knowledge • Lack of investment • Lack of experienced local workforce and skills	• Working with foreign company as joint venture • Upgrade the traditional construction system in to modular techniques • Government support local construction companies in finance	(Aigbavboa, Aghimien, & Ntso, 2018; Mostafa et al., 2014)
Ghana	• To solve housing problem in the country • To minimize waste in the construction industry • To substitute imported construction materials by producing prefab elements from local materials	• Limited awareness of the technology in society • Limited technical capacity of local contractor • Shortage of skilled personnel, and lack of industry knowledge • Lack of investment depend only on foreign contractors	• Localization the construction materials • Working in advocacy to the community • Introducing foreign company in housing industry • Introduce the foreign constructors through FDI • Government-to-Government aids	(Essienyi, 2011; Osabutey & Jackson, 2019; Osabutey et al., 2014)

2.6.2. Summary from the practice of other countries

From the above literature of different countries most of the countries were practiced from other countries in various ways. Prefabricated building was an effective tool in solving acute housing shortages in developed countries. And, those developed countries doing more in transferring the technology and adoption appropriately by researches and studies to settle with their local resource, economic, social, and geographical phenomenon. However there were some little challenges in diffusion the technology like shortage of market demand, lack of expertise on the technology, lack of standardizations in house construction etc.

On the other hand on developing countries especially in African countries there was lack prefabrication technologies but have proposed several policies for mechanization or prefabrication in their respective construction industries. However its development was limited due to different factors. Shortage of financial fund, low technological adoption capacity, restrict policies and regulations, shortage of local expertise, absence of focus on research and development, lack of standardized building practice, import based construction practice, and etc. was among the different challenging factors in adoption of prefabricated building construction technology.

2.6.3. Ethiopian Practice on prefabricated building

In Ethiopian the history of prefabricated construction starts from Axum civilization. During that time Axum obelisks were constructed by detaching huge rocks from mountains around west Axum, and then transported to the current standing position. The other implication of prefabrication construction in Ethiopia was the stele of ‘’Tiya’’. Therefore the prefabrication construction history starts before thousands years ago. But the modern Prefabrication building construction in Ethiopia began with in the late 1970's and 1980's, the vast demand for housing and only the government being the facilitator for shelter could not meet the ever rising demand.

The role of prefabrication in building construction has been lauded for its potential to increase productivity and efficiency without compromising the quality. The same to that prefabrication have the potential advantages of realizing housing quickly and affordably as developing countries are suffering to fulfill the housing demand(Geleta, 2019; Tessera, 2020). Developing countries continue to embrace technology from their developed country partners/supporters(Dimitrijevic and Jovancov,2000). This trend does seem to slowing in developing countries like Ethiopia. Prefabrication building construction in Ethiopia began with in the late 1970's and 1980's, the vast demand for housing and only the government being the facilitator for shelter could not meet the ever rising demand. As a result it was decided to introduce a new building technology, the prefabrication of concrete structural elements. According to (Dimitrijevic & Jovancov, 2000) in Ethiopia (Addis Ababa), a factory of the IMS building technology was erected in 1983, with the purpose of constructing residential and office buildings, and the annual capacity of 50,000 square meter. Transfer procedure was by elaborated feasibility study and proving the difference in cost by comparing with actual conventional construction method. Although the feasibility study depends on the data from the certain region of receiver country population, industrialization level, number of employed personnel, data on raw material of receiver country, trends of further development, and potential of investment.

In Ethiopia also the (Integrated Modular System (IMS) institute of Yugoslavia implement the transfer of building technology through the designing (service and product), Engineering (product), and consulting (service) form. The engagement within the framework of technical assistance in Ethiopia was 10 worker/months, carried out by 5 experts from Yugoslavia and giving training to Ethiopian workers. The technical assistance was obtained from the former Yugoslavia and the IMS system, of a Yugoslavian firm with more than 30 years of experience in the field was selected. In 1984 Prefab Housing Factory for prefabrication was established and organized administratively under the former Ethiopian Building Construction Authority. Finally the factory was started production of building structural elements in 1986.

Later on accordance with the new economic policy in 1993 Prefab Housing Factory at a department level under the former Ethiopian Building Construction Authority was reestablished as business entity and known as Prefabricated Building Parts Production Enterprise (PBPPE). At the current time precast concrete beams and agro stone wall panels in a greater amount relative to other components those made with small, medium and large industrial fabrication, that uses for floor/slab and internal partition wall construction in Ethiopia.

Table 2-2 percentage of expansion of prefabricated building in Ethiopia

City	AA	Debrezeit	Nazareth	Hawassa	Dewale	Galafi
Prefab expansion %	87	4	2	2	2	2

Source (Tessera, 2020)

2.6.3.1. The Integrated Housing Development Program (IHDP)

As a response to the high housing stock demands, in 2005 the Council of Ministers of the Federal Democratic Republic of Ethiopia established and instituted an amalgamated effort that came up with a Consolidated Urban Development policy that links the various scales of housing stock delivery efforts in the country. This effort also led to the establishment of the national Ministry of Works and Urban Development (MWUD), which was made responsible to oversee the urban development process. Within the structure of the Ministry of Works and Urban Development (MWUD) the National Urban Planning Institute is responsible for preparing appropriate urban development strategies and plans that respond to the existing housing stock needs. In collaboration with the National Urban Planning Institute the Housing Development Bureau has been working to implement the Integrated Housing Development Program and its parallel programs such as the Micro and Small Enterprise Program (MSE) initiatives. As a result the MSE has the responsibility of manufacturing prefab elements for the condominium housings when the government was help in financial subsidiary. The Integrated Housing Development Program (IHDP) is a government-led and financed housing provision program for low-and-middle-income households in Ethiopia. The program was launched in 2004 (1996 in the Ethiopian calendar) by Arkebe Oqubay the Mayor of Addis Ababa. Within the IHDP, specific projects are undertaken on either brownfield sites or slum areas that are cleared and residents re-housed.

During its start time the project shows a little success but it does not mean no failure; he fact that the problems are vast and sophisticated, practical skills on the construction technology are limited, financial, human and physical resources are inadequate and efficient professional and institutional management capacities are imperfect(Ali, 2009).

2.6.3.2. University capacity building Program in Ethiopia

University capacity program was a program with an objective of constructing 13 university projects together with capacity development of domestic construction and consulting firms. The program was designed and implemented with involvement of Germany technical assistant international service (GTZ IS) as a project-implementing agent(Ayalew et al. , 2016). Technical and management assistant is being provided by the GTZ. The aim of this program was to increase the capacity of local contractors with new construction methods; like prefabricated techniques, management systems and etc.

2.6.3.3. Utilization of local building materials and technologies

Ali states that to transfer and adopt new technology in building construction utilization of local building materials and linking with the imported technologies was important issue. Building materials often constitute the single largest input to Building construction in Ethiopia. It is estimated that the cost of building materials alone can take up to 70 percent of a standard low income formal housing unit(Ali, 2009). Despite the fact that we are endowed with abundant natural resources that can meet our need for building materials production, we depend largely on imported building materials and technologies(Ali, 2009). No considerable research is conducted in Ethiopia that initiate and disseminating findings to the potential users. Currently, Agro stone is being used for partition and other ancillary works. The raw materials for agro stone are agricultural raw materials as filler (70-75%), minerals as binders and bond accelerators and fiberglass as reinforcement. The materials are non-poison and has good resistant to radiation, it is sound proof, water proof and acid resistant, it can withstand fire up to 118 minutes, ...etc.(Tessera, 2020). The technology is imported from china and we now have qualified professionals and production centers in Addis Ababa.

The other prefabricated building technology introduced to Ethiopia was Sustainable Incremental City Unit Experimental building with focus on affordability and adaptability funded under the 'Welcome to Africa' program of the German Academic Exchange Service. Sustainable Incremental Construction Unit is a process-oriented building prototype that also deals with participatory design to be done in a highly dense neighborhood of Addis Ababa. It will be a showcase where the team of students with their tutors will research and explore possibilities of designing and realizing an incremental housing unit in an urban context. The aim of this project was to solve shortage of housing in Africa by building home with entirely prefabricated elements using locally available materials. The SICU collaborated with EiABC and trying to produce walls combine materials such as wooden boards and rubber sheets from tires. It is provided as a semi-finished construction that the homeowners then complete themselves. Simple building elements and a clear construction principle using prefabricated concrete elements (foundation and columns) are combined with lightweight timber frames and readymade wall panels with integrated windows and doors. Basic parts of the house was built within less than two weeks by participating local small businesses and local community(*Sustainable Incremental Construction Unit*, 2017).

Figure 2.3 prototype prefab home built by SICU at EiABC ("Sustainable Incremental Construction Unit," 2017)

2.6.4. Common Prefab Elements products in Ethiopia

According to (Geleta, 2019)the following are the most common prefabricated elements used in Ethiopia. Those are panelized wall, precast concrete elements, light gauge steel frame, Calcium silicate board, Magnesium board, Agro stone panel, and Industrial steel shades and Containers.

Panelized Wall: is Building System is a construction technique that utilizes advanced technology, quality materials, and a controlled work environment to build wall panels and construct a durable, energy-efficient structure in less time and with reduced environmental impact. A panelized home is just like a stick built home - Except it is simply the process of making wall sections off-site in a manufacturing facility instead of out at the construction site. Wall panel may made of plastics, woods/Timbers, steels and other local materials. Currently experiencing wall panels in Ethiopia are timber and local material wall panel made straw which glued by chemical was experienced by the EiABC ("Sustainable Incremental Construction Unit," 2017).

Agrostone panel is composed of agricultural/industrial wastes and/or lightweight natural minerals as fillers, magnesium-based chemicals as a binder and fiberglass as reinforcement. The technology of Agrostone panel production had been practiced in Asia and Latin America. All countries adopted the Agrostone panel production technology based on the availability of the raw materials on their own countries(Taffese, 2012). Likewise, Ethiopian Agrostone production center has adopted from China and India and production materials are:

- Fillers for Agrostone panel production can be agricultural products and/or lightweight natural minerals like pumice and diatomite and agricultural product, bagasse which is available from a number of inland sugar factories. Bagasse has two main advantages. One of the advantages is its high tensile strength and elasticity modulus properties(Ministry of Finance and Economic Development & Ethiopia, 2010).
- The binder of Agrostone was fiber glass which is waste from glass production use as binder as binder and chemical additives like MgO , MgCl are added.

The fitness of Agrostone panel as construction material in Ethiopia was due to reducing construction cost and time, easily produced in different shapes, sizes and different forms, and as it utilizes large labor force in its production process makes it convenient for developing countries with high unemployment, at the same time it goes in line with local mineral resources for its production(Taffese, 2012).

Precast frames and panel is a panel and building system provides easy standardization, speedier construction, cost-effectiveness, high quality finish and enhanced facade design. Pre-cast system is more economical for high-rise apartment projects. In Ethiopia the former PBPPE produce prefabricated elements (the main products are, columns, beams, ribbed slabs, U-shaped blocks and stairs) and the IHDP with collaborating to MSE (Micro and Small Enterprises) used prefabricated elements to construct condominium houses around all the country. Contractors also produce precast blocks by themself in remote area to construct fast and overcame the shortage of construction materials(Taffese, 2012).

Magnesium Board Magnesium oxide board, "MgO-board", is a factory-made sheathing board product, which has been widely used in the last +10 years in ventilated facades on new or renovated buildings in Ethiopia. It can be used for a number of applications including wall and ceiling linings, fascias, tile backing and underlayment. YBEL Industrial Building change is currently producing MgO board for different purpose of building construction(Dinku, 2017).

Calcium silicate board is a fireproof board with an inorganic and non-combustible A-grade quality composed of different silicon minerals and having stable physical and chemical properties. It does not lose its form in any temperature or moist air and it can handle temperatures up to 1100℃. It is almost a kind of permanent material with characteristics such as lightweight, good dimensional stability and high strength. Calcium silicate board is not only a fireproof board but can also be used as a decorative material. It can enhance the form of the steel beam and column making the beam and column very straight and square which will make the decoration very attractive. Calcium silicate board introduce by Addis prefab housing manufacturing industry in Ethiopia as walling material(Www.adisprefab.com, 2015).

Light gauge steel: Steel building system in which the load-bearing structure, consist of the wall framing, columns, beams, trusses, panels or any combination of these to make a steel building. This method of method was first introduced by Australian scientists and spread to Asian and Europe countries. In Ethiopia also introduced by China Company and, after a time Addis prefab housing manufacturing industry start to produce LGS in Sendafa but not continued due to fraud.(Tessera, 2020).

2.7. Relation technology transferring on prefabricated building

As previously defined Technology is ; a (a) physical component which includes products, equipment, techniques, and processes (b) an information component, which includes know-how about management, marketing, production, quality control, reliability, skilled labor, and functional areas(Uusitalo & Lavikka, 2020). Depends upon the definition of technology the study of technology transfer cannot only focus on the product, because the product needs to be transferred with the technique and knowledge relevant for its use and implementation. Osabutey et al., (2014) concept underlines the combination of the technology and the related required knowledge and techniques of application. The prefabrication knowledge was started to import to different countries during 1950’s. Designers and contractors tried to identify a specific schematic design for prefabricated buildings market, since the suitability of different kinds of construction methods to promote their knowledge and product to make ready for the market. The main advantage of prefabrication construction is its easy way to transfer new and advanced technology to the industry(Girma et al., 2020). Therefore actors participating in technology transferring should supply and adopt all means, skills, know-how, knowledge and appropriate to the local scheme of the country; and not only to select, master and adapt the technologies that are needed in production.

As Wubshet identified prefabrication technology is one of the current demanded construction technologies to be adopted and saturated to whole of the country to solve different challenges in execution performance as well as to overcome the shortage of housing in Ethiopia. According to Jakele on 1st Construction Profession Week Magazine, (2017) prefabrication is one categorization of construction technology. The labor-intensive characteristics and high non-recycled resources consumption has made residential building construction; as the main contributor to the poor environmental performance and more resource wastage (Shen, 2010). Due to this reason the use of prefabrication building construction method was implemented in different countries of the world to challenge this problem. Factors that necessitated the investigation for new technologies and flexible policies in construction includes; the rapid increase in population due to the rapid increase in the migration from rural to urban areas this growing in population asks to use prefabricated building. Ethiopia has tried to transfer the technology before four decades however, it not meet the target of needs(Girma et al., 2020; Tessera, 2020).

2.8. Challenges of technology transferring in prefabrication technology

Studies conducted (Ofori, 2006; Uusitalo and Lavikka, 2020) indicate that the degree of absorption and diffusion of technology depends largely on the level of knowledge and other supporting infrastructures available to a recipient. Similar findings show thus, it is important for organizations or countries to interact one another to exchange technological knowledge (Mselle, 2014). However, TT can be affected by numerous barriers those are; low vertical integration in supply chain, low or no investment on research and development (R&D) as R&D help in innovation, lack of collaboration and limited knowledge sharing during subcontracting: projects are team-based and lost their linkage when project ends and team break-up, policy problems no fixing the amount of subcontracting when contract is awarded for foreigner company(Ofori, 1990; Kebede and Mulder, 2008). Also developing and adopting new technologies face a series of obstacles and barriers in each of the stages of their development and commercialization.

Technology transfer to developing nations is not much easier and often it is a complicated process in technical, economic, social, political and legal aspects of the transferor nation. The main challenging factors in transferring of technology in construction industry of developing countries was discussed below in detail from different scholars.

Limited enforcement of prefabricated construction approach requirements:- As the contribution of both government and private sector has contribution in TT; the governments should initiatives to increase the utilization of prefabrication practice for every construction projects(Amin, et al, 2017). In developed countries utilization of prefabrication practice for every construction projects was mandatory for both private and public buildings(Matsumura et al., 2019) construction, however in developing countries like Ethiopia the execution process was believed not strongly enforced(El-Abidi et al., 2019). Apart from that, utilizing prefabrication building system means there was a necessity of specialized equipment and machineries requirements. Based on previous studies, lack of these equipment and machineries especially to local contractors in developing countries proves to be a major hurdle that hinders work in prefabrication building projects(Girma et al., 2020; Matsumura et al., 2019).

Lacking knowledge and expertise on prefabricated technology:- (Tessera, 2020) pointed that the current curriculum did not address prefabricated technology comprehensively especially in Ethiopia. Lacking expertise of contractors may lead to delays such as erecting the prefabricated structure and panels (Polat, 2010). Meanwhile, the prefabricated construction technique adoption, characterized by a high degree of mechanization, necessitates the presence of sufficiently highly qualified construction workers (Polat, 2010). .

Availability of low wage labor:- Studies had indicated that the availability of cheap local labor which offsets the cost benefit of using prefabricated construction was the root cause of the slow adoption in the past(El-Abidi et al., 2019). As long as it was easy for the industry to find workers especially in developing countries, labor rates would remain low and builders would find it unattractive to change into simplified solutions such as prefabricated construction method. At the same time, government body shows this as job creation and not motivate to use modern technologies. The system demands more machine oriented skills, both on sites and in factories. Thus, this leads to a transformation requiring the restructuring of human resource in an organization in terms of training and education Generally, Ethiopia is still lacking of skilled worker(Chane, 2017; Tessera, 2020)

High initial cost and initial fund problems: - In prefabrication construction approach, one of the drawback was its high initial cost. Payment and procurement mechanism needs to be reviewed to tailor to prefabrication construction method activities which are reliable and for safer payment and procurement. Change in construction methods and processes from conventional to prefabricated will affect the change in the mode of payment and any related clauses in the contract(Hong et al., 2018; Polat, 2010). Contractors in developing countries have a shortage capital, this make them difficult to introduce and apply new technologies (Baghchesaraei et al., 2016).

As for Ethiopia, the prefabricated construction adoption lagged behind developed countries arguably due to higher initial cost. Besides, the required skilled labors might induce higher cost especially in developing countries like Ethiopia skilled labors are imported. And the local labors are lower their wage (Tessera, 2020). related to this education and training for unqualified labor also incur cost (Girma et al., 2020; Girmscheid, 2005).

Limited market demand: - The limited market demand presents significant challenge for any salesperson and or developer, so the feasibility of adopting prefabricated construction will be doubted (Mao et al., 2015). This will lead to client's doubt and resistance who actually determines the prefabricated construction adoption. Meanwhile, due to fluctuations in the market demand for Prefabricated construction, high upfront payments are required by manufacturers in order to keep their production and distribution system profitably (Steinhardt and Manley, 2016). When the prefabricated building element production and distribution was limited only on government institution the marketing promotion is not meet the targeted aim(Ali, 2009). This has been regarded as one of barriers to the wide adoption of prefabricated construction mainly attributing to failing to achieve economic scale effects (Arditi et al., 2000).

Low standardizations: - Low of building components also hinders successful use of prefabricated building system. The tailor-made components which do not fit into another project will increase initial costs due to the cost of the mold and design. Lack of standardizations was due to a lack of a certification and accreditation scheme on prefabricated building system and the lukewarm response to Modular Coordination(Mostafa et al., 2014; Tessera, 2020). Therefore the adoption and development of prefabricated building construction was depend on the amount of work to be construct. There is a general consensus among practitioners that prefabricated building needs mass production to achieve economic viability, but currently, in Ethiopia, there is no assurance of continuity of production, thus limiting interest in prefabricated building.

Inadequate feasibility study: - In developed countries there is a lot of study to utilize prefabricated building construction techniques. And they tried to understand first the way of implementation and spreading in throughout their countries(Gan, et. al., 2018). However in developing there was a huge gap on planning and performing.

Limited use of information technology among construction firms: - Technology diffusion through the flow of information usually takes different routes such as information dissemination among research institutions through technical journals, research bulletins, and specific networking arrangements with regions and by the exchange of technical personae on study tours. Such a flow of information is also common between research institutions in developing countries and certain industries in developed countries interested in marketing their technologies to developing countries. Currently, the cooperation between contractors, manufacturers and suppliers is weak in many cases. In adopting and spreading information new technology the value of central and up to dated information has great role. However in developing countries like Ethiopia there was a shortage of information sharing among construction firms. Studies shows in construction industry there is a problem in documentation.

Shortage of infrastructure to utilize the technology: - The infrastructure implies the necessary institutional makeup as well as the necessary physical conditions for transferring technology. As nature prefabricated technology needs high infrastructure accessibility to produce, utilize and move from place to place(El-Abidi et al., 2014). Based on previous studies, lack of these equipment and machineries proves to be a major hurdle that hinders work in prefabricated based projects and adopting a new system; means that more time needed to be allocated for training of human resources, specialized equipment and machineries. In Ethiopia there is high gap in infrastructure in all corner of the country. At the same time this make difficult to adopt and diffuse prefabricated technology(Tessera, 2020).

Lack of stake holder participation: - In fact, the construction industry is very conservative. It cannot use the trial-and-error method for innovation because failures have grave consequences for public safety. An owner who will occupy the structure will not tolerate any unnecessary risk or potential liability caused by using a "new" technology. The competence and cooperation of stakeholders is critical to the success of the technology improvement of construction projects

Communication. Construction project starting from contract the quality management work with knowledge, coordination, legal frameworks and information exchange is essential point(Gan et al., 2018; Geleta, 2019).

Language barriers: - In technology transferring the difference in language among the transferor and transferee was have negative effect on its direct acceptance. As the host country was supply the labor and other staff resources during the construction period the difference in language matter on the acceptance capacity of receivers(Bakar & Tufail, 2012).

Shortage of building codes and standards: - Building codes are written to establish a minimum standard of quality and performance for buildings in a specific area. These codes must cover every type of building and every site condition. It is impossible, however, to address the unique characteristics of each construction project, so the codes are written in general terms and interpreted by local officials for specific applications. In other words, the codes are based on the common practice for the area of application; this can be a barrier to importing a technology that is not common to the area. If the local officials do not have the technical expertise and are unwilling to seek expert consultation, then the code interpretation may restrict the potential innovator from transferring and modifying the "new" technology(Tessera, 2020).

Government Policy: - Government regulation can mostly be found in the third world and developing countries. It deteriorates investor confidence from developed countries. Most investors rely heavily on democracy and political stability because they expect money return from continuous investment policies. Government regulations often mean changes in a country’s policy. Thus, any perception of government regulation by investors leads to the abandon their investments in a host country. As a result, financial inflows and new technologies will not go into the host country(Fordjour, 2015).

Lower technology absorption capacity: - Absorption Capacity Most transferee firms lack infrastructural and organizational capacity to absorb the transferred technological capabilities. Absorption capacity is the ability of a firm to recognize the value of new external technology, assimilate it, and apply it to commercial ends(Jakele, 2017; Mulu, 2018). Poor absorption of technology. Marketing capabilities is the major variable that affects the TT process both negatively and positively (Osman-Gani, 1999). Marketing capabilities of TT includes planning, scheduling, programming, training, and making the operational environment ready for the newly obtained technology.

2.9. Technology transfer Mechanisms

Finding what to evaluate is the main trouble, subsequently technology transfer has two main dimensions: that from the seller to the buyer, and that relating to the effective diffusion and application of the technology(Ofori, 2006). The need to effect, and even rush, the advancing exercise suggested by Raftery et al. has led many developing countries to institute measures including: (i) mandatory joint ventures; (ii) mandatory subcontracting; (iii) specified training of local personnel; (iv) Imposition of floor limits on projects for which foreign firms can tender; (v) differential taxation of foreign and local firms; and (vi) offering of tendering preferences to local firms. From these according to UTCAND the joint venture appears to be the most widely preferred vehicle of technology transfer in construction. Especially in transferring specific product like prefabrication construction joint venture and subcontracting are the most preferred channel of transferring. On the other hand there are two mechanisms of acquiring technology which called ‘’generation’’ and ‘’importation’’ when the first one development of new technology and the other one is the process of obtaining technology from others and development of skills to adopt. According to Jakele, (2017) TT in construction industry can be categories as;

1. Direct TT methods/Channels including independence between transferor and transferee (i.e. avoiding trade barriers) and strictly contractual agreements in technical assistance supplying, delivery methods franchising etc.
2. Indirect TT Methods/channels including joint venture (equity & contractual), foreign direct investment on physical or capital only, multinational direct investment, subsidiary, sub-contract, licensing, and patent and trademark branding.
3. Industry Linkage through R&D with Universities, Non-Governmental Organizations (NGO), and societies.
4. Trainings direct purchasing and import substitutions

UNCTAD suggests that TT should be arranged according to the level of economic development, infrastructure gaps and technological deficits between the sender and receiver. The United Nation (UN) suggested international joint venture as potentially effective channel for TT in developing countries (Devapriya), 2010 and (Ofori, 2006) listed the following main technology transferring mechanisms that most applied in construction industry; includes subcontracting, licensing, foreign direct investment (FDI), joint ventures and training, the success of each mechanisms may vary under different circumstance(Ngowi, 2002). The following common channels/mechanisms of technology transferring in construction industry was discussed below from different literatures and used to collect individual perception of respondent in the questionnaire part.

Research and development (R&D):- The role of Research and Development (R&D) in generating new ideas, and continuous improvement for administering the construction industry is not to be underestimated(Jakele, 2017). The various previous works in this field stated that the extent of research and development (R&D) in the field of prefabricated building construction is limited in terms of the development of local design and a manufactured building system, new materials for prefabricated building components, modern approaches and innovations, and advanced scientific information(El-Abidi & Ghazalia, 2015). Many researchers in developed world have explored the potential of R&D in prefabricated building construction especially in terms its development and improvement of imported technology(Hong et al., 2018). The government should pour more funds into research grants through the relevant agencies and offer a wide range of incentives, such as tax reductions, and increased R&D inputs in the construction(Gatew, 2011).

Joint Venture: - It is a strategic alliance between two or more parties in combining their interest to undertake economic activity together. The parties agree to create a new entity together by both contributing equity, and they then share in the revenues, expenses, knowledge and resources to develop a technology, produce a product, or use their respective know-how to complement one another. Benefits from a joint venture in case of technology transfer are the following: long-term cooperation between the parties, motivation of all participants in the successful transfer, lower costs than if the companies have been working separately(Osabutey & Jackson, 2019).

Developing countries create joint with experienced foreign companies to get the required technology. The foreign company provides innovative technology and management competence, while the local company is familiar with the market and regulation. Finally it is difficult to determine the value of each asset(Mulu, 2018). In construction industry companies were collaborated with specialized companies in specific work as Joint venture to perform project as the required quality and time(Rameezdeen et. al. , 2005).

Foreign Direct Investments:- Foreign Direct Investments (FDI) is one of the main methods of technology transfer at the state level. Generally, a foreign company invests in developing countries in order to create a new market, remove export barriers and get an access to cheap labor and natural resource(Ofori, 2015). Direct foreign investment can transfer technology in two ways. An “internal transfer” occurs when there is a flow of knowledge from foreign investors and experts to the local work force within foreign subsidiaries. Internal transferring occurs within a firm through observation, through on-the-job training or through formal training. An “external transfer” occur when trained local staff or skilled local entrepreneurs leave foreign subsidiaries and take with them those fostered skills which cannot be appropriated by transferors.

Trainings: - In addition, technology experts agreed training was best way for technology transfer in developing countries (Ofori, 2006). For countries like Ethiopian on job/field training was important as the number of unskilled laborers are available. Beside to this, short training aboard and locally by experts will effectively enhance technology transfer and development in management and innovation practices in short period of time. Industries and government office give training in aboard with collaboration with foreign companies(Almutairi, 2015).

Turnkey Contract: - A turnkey project is one in which an organization undertakes the construction of a production facility and turns the key to a host company or some other organization when the facility is ready for operation. A turnkey project may also include the training of domestic personnel to eventually take over the operation of the factory. It is worth noting that in a turnkey investment domestic personnel are able to operate the new plant but may lack the ability to set up a cement factory or a sugar refinery. The ability to reproduce or set up a production plant may indeed be more beneficial in terms of fostering self-sustaining development in the long run than having one from a turnkey arrangement in which the recipient only consumes or operates the technology involved(Fordjour, 2015). However, (Ofori & Ofori, 2006) argues that the advantage of having a number of separate contractual agreements is that they encourage the development of ‘national technological capabilities’. Despite these arguments, it seems that much reliance upon ‘turnkey’ contracts may cause delays in indigenous development of those skills required to organize and set up production facilities in developing countries**.**

University industry linkage: - used to obtain practical skilled, and helps in flowing knowledge from educational institutions to industries, and vice versa. The implementation technique of UIL & TT could be trough internship, externship, and joint agreement (Abate, 2020).

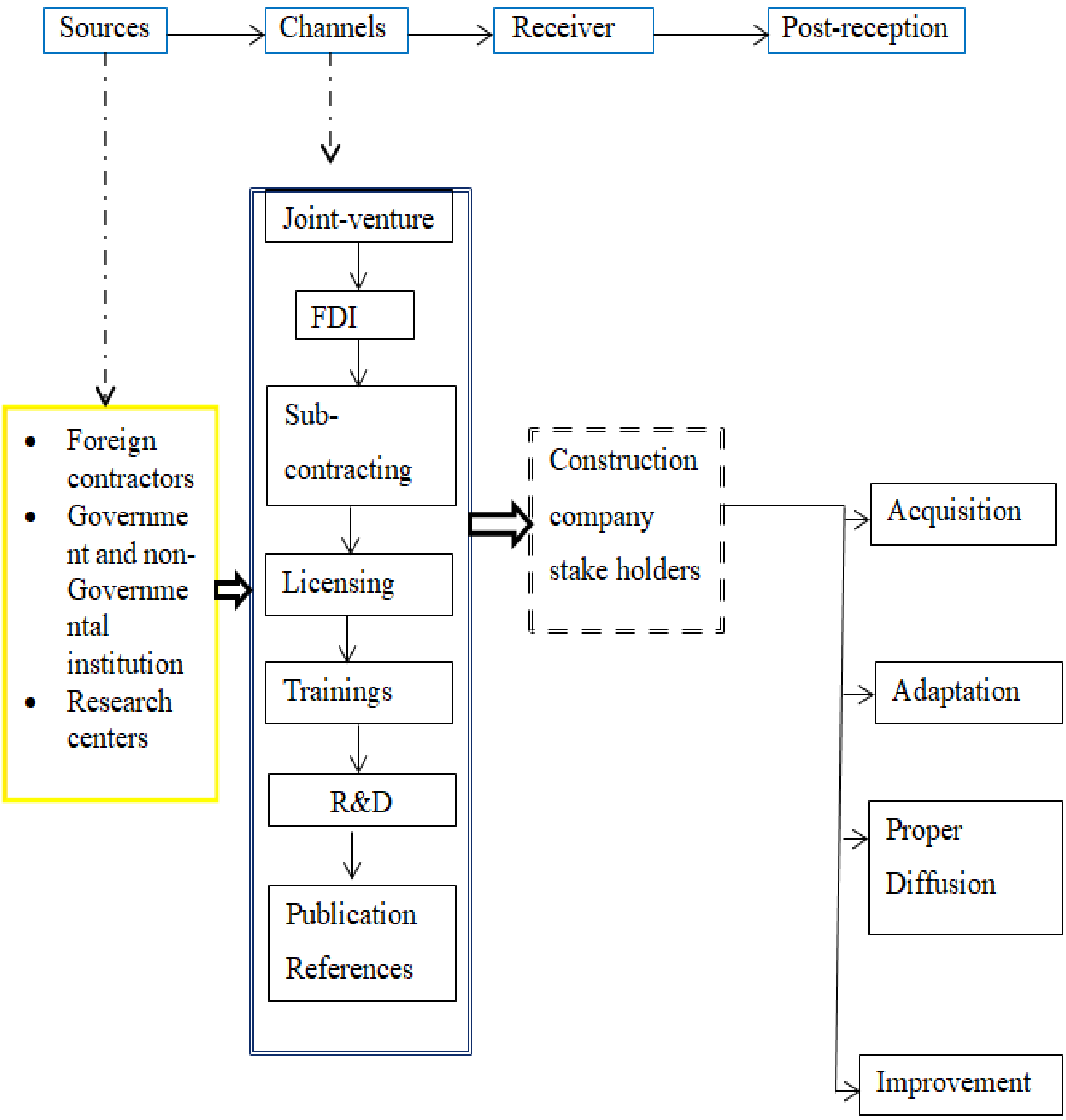

Figure 2.4Construction technology transfer channels and process (source: (Ofori, 2006; El-Abidi, et al. , 2014)

2.10. Research gap

In previous studies technology transferring in construction technology as a whole was conducted, but it not specified. The three main criteria that exist across various fields of science are product, process and knowledge. When studying TT in a construction context is can fulfill one of these three TT criteria. As construction applies as project oriented approach most of the processes are transferable from one project to another. In many literature prefabrication building construction was includes all those technology criteria's, and helps in technology transferring. Although studies on the elements of prefabricated building and their application are well studied. The advantages gained through prefabricated construction technique and application area of prefabricated construction was studied. In Ethiopia the practice applying prefabricated construction technology in the CI is still lags behind; and the challenge on its development of the practice related to its starting time, and benefit gained from its application with comparison to transferor countries is not studied. From this point the study on challenges on technology transferring and ways of its transferring was gated vital to develop the construction industry. This study was starting from scratch and trying to identify the challenges of spreading out prefabricated building and best ways/channels of transferring to the technology. Construction technology transfer arrangements cover different from of technologies, ranging from those relating to particular techniques, systems, materials or tools to the complete design or construction (or both) of projects. This paper concentrates on the transfer of techniques to contracting firms. Such transfers do not always involve "modern" or advanced technologies (which have been given emphasis), but may be concerned with appropriate technologies.

3. RESEARCH METHODOLOGY

After generating the research questions and reviewing the literature in the previous chapters, the methodological approaches adopted in this thesis will be discussed in this chapter. It provides information about the research location, research design, target population, sampling procedures, methods of data collection, research instruments, and the last thing is the process of data analysis.

3.1. Description of study area

The study was conducted in Addis Ababa which is the capital of Ethiopia lies at an elevation of 2,355 meters (7,726 ft) and located at 9°1′48″N 38°44′24″E. And the population of Addis Ababa city was 3,384,569 according to the 2015 census of Ethiopian Central Statistical Authority (CSA, 2015). This capital city holds 527 square kilometers of area in Ethiopia. The population density is estimated to be near 5,165 individuals per km^2 available. Addis Ababa is the major commercial, industrial, educational and political center of the country. The reason to select Addis Ababa as representative area is 87% of the prefabricated building construction activities and new technologies are first implemented in this city(Tessera, 2020).

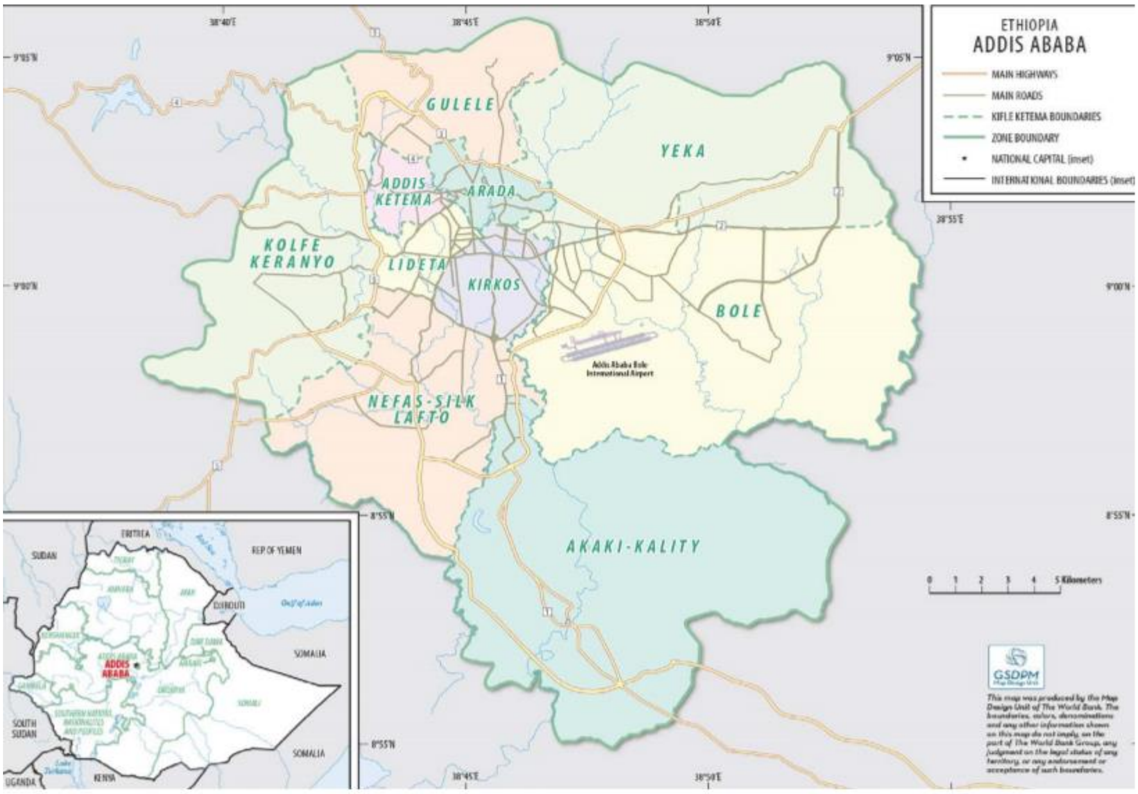

Figure 3.1 Map of AA city

(Source: (Google Map 2019, Accessed November 09, 2019)

3.2. Research design

Research design shows how all of the major parts of the research study work together in an attempt to address the research questions. It is a logical model of proof that allows the researcher to draw inferences concerning causal relations among the variables under investigation and also it deals with at least four problems: what question to study, what data are relevant, what data to collect and how to analyze the results. In order to get appropriate information, the researcher was used survey as the population is large in number and there exist financial and time limitations to conduct survey. To investigate the construction technology transfer challenges on the acquisition and development of prefabricated building, this study adopted both qualitative and quantitative research design was; given the limited local knowledge and technical know-how on prefabricated building technologies as well as the lack of literature in the implementation of such projects in the Ethiopian construction industry. Quantitative approach is used to gather factual data and to study relationships between facts and how such facts and relationships accord with theories and the findings of any research executed previously, but the qualitative approach seek to gain insights and to understand people's perception of "the world" whether as individuals or groups(Udochukwu, et al., 2017).

3.2.1. Target group/population

This study addresses this topic based on the perspective of construction sector professionals and academicians in Ethiopia. Therefore the targeted population surveyed for this study were experienced with general and Building contractors; building material merchants also to study the challenges during design and supervision consulting companies were surveyed. A public owners sector also has participated on the survey as prefabrication was introduced by the government. The other population of this survey was academicians and researchers were participated in this survey to get their perception on the technology in Ethiopian.

3.2.2. Sample

Sample was also selected from the population using both probabilistic and non-probabilistic sampling techniques. Whereas the purposive sampling was used for the interview and simple random sampling technique was used to conclude the population in the questionnaire survey. To minimize the time and to get relevant information in collecting data using purposive sampling technique is good; as which is help to get experienced practitioner on prefabrication building construction. There for the interview purposive sampling was used. As well as to measure the perception individuals in the construction industry random sampling was used for the survey 346 questionnaires was distribute for the selected participator contractors, manufacturers consulting offices and government bodies and Academicians by google form on online and in person for those who doesn't accessible for the google form. For the unknown population the sample size was be to determine by Cochran's formula for unknown population as follow;

$$n_o = \frac{Z^2 pq}{e^2} = \frac{1.96^2 (0.5)(0.5)}{0.05^2} = 384 \quad \text{(COCHRAN 1977)}$$

Where; Z= 1.96 from Z table for e=95% level of confidence (e=0.05% margin of error) P, the estimated proportion of population which has the attribute in question p=0.5 q, is 1-p; q= 1-0.5=0.5.

As the formula give 384 sample size but I have distributed only for 346 participants because, I have accessible to those participant when the construction was no more active due to the CoVID-19 during the period of this study.

3.3. Data collection

The researcher was used both primary and secondary data, the primary data will be in a form of questionnaire, designed to gather a large volume of data from stakeholders who were contractors, consultancies, and a researchers/academicians. A semi-structured interview was used to collect data from regulatory bodies, because of prefabricated technology was initiated and introduced by the government this help in getting a rich data.

3.3.1. Primary data collection

The primary function of the survey is to collect information that can be analyzed and interpretation made to produce conclusion about the study. As well as a case study was adopted in this study. The target group for the case study was selected based on their experience and the knowledge they had on the prefabricated technology that have been transferred to their organization. Discussions with different stakeholders would be conducted to learn stakeholders understanding, opinion and view on the conventional construction method and the proposed prefabrication technology.

- Questionnaires

Questionnaires are a tool for gathering invaluable data about attitudes, values, personal experiences and behavior. Unlike experiments, surveys are conducted on a wider population using economic data collection methods (Saunders et al., 2007). Questionnaire design begin with the creation of an extensive literature review sample questionnaire. On 23 participants, a pilot study was conducted to check the validity of the study. Structured questionnaire was designed, in to two parts and four sections to answer the research questions and distributed and collected through google form in online from to the sample respondents. The size and the layout of the questionnaire designed to make completion as easy as possible taking into consideration the targeted population. Where possible the answers are given in a multiple choice format and ranking format. Where open-ended questions are asked, there will be little space left for answers to encourage brief answers, partly to ensure that respondents do not spend too long on these questions. Question wording were specific and simple and the vocabulary used kept as simple as possible. The questionnaires were sent via email to the internet accessible participants and in person for those not accessible participants.

The content of the questionnaire has three sections when the 1st section includes the general information about the respondents, and the second one was questions to answer the current practice of using prefabricated building technology and way of transferring. At the same time the second section include the challenges of transferring, adopting, and diffusing sustenance ably the technology in likert scale format. In the last section the best ways of prefabricated building construction transferring questions was formed in likert scale format to rank their result by computing Relative Important Index (RII).

- Interviews

The purpose of interviews was to allow for probing and the clarification of responses for the participants to give their detailed perspectives on challenges of transferring prefabricated construction systems and causes of slow adoption and spreading across the country by government bodies in the construction industry. Primarily, the interviews involved semi-structured questions to allow the researcher to gather valid and reliable data, thereby making sure that they answered within the confines of the research objectives.

➢ Case study

The case study method is an intensive analysis of a single case. It can take the form of interview notes, observations and video material, documents and records to provide an in- depth investigation of particular instances with the research subject.in this study the case was from one current active prefab element producer company and one unserviceable company in Addis Ababa. The active prefab element producers are currently participating in the construction industry of Ethiopia by producing prefab elements (Low cost housing projects). Whereas the other stopped building homes with prefab elements was Addis Prefab manufacturer and Producer Company.

3.3.2. Secondary data collection

In the secondary data which involves information from published document such as academics publications, journals, government publications, past research papers and internet resources are used to support the primary data.

Table 3-1 Research objectives with corresponding data collection tools

Research objectives	Data collection techniques			
	Literature	questionnaire	Interview	Case study
To assess technology transfer practice in Construction Industry considering prefabricated building elements in Ethiopian construction industry:	√	√	√	√
To identify the challenge in transferring and ensuring sustenance of prefabricated building elements in Ethiopian construction industry.	√	√	√	√
To identify effective technology transfer mechanisms of prefabricated building construction	√	√	√	√

3.4. Data management and analysis

To meet the specific objectives of the study the data collected from both primary and secondary sources require rigorous analysis and interpretation, for this study descriptive statistical analysis was used to provide comprehensive and meaningful results using SPSS (statistical package for social science) and MS Excel. For the data form interview and case study was analyzed by coding and contextualizing key attributes from the respondents. Data presentation techniques were used depending on the nature of the data. The analyzed quantitative data was presented by using tables, graphs, percentages, and narrative descriptions. The qualitative data was simply discussed and analyzed qualitatively in a way it present the information properly. For the likert scale questions the mean index and frequency was calculated by SPSS.

After calculating the mean, one sample T- test was used to identify significant difference (important variable from the questionnaire survey) with a predefined value for challenging factors used for the purpose of discussion. A t-test is a type of inferential statistic used to determine if there is a significant difference between the means of two groups, which may be related in certain features.

3.5. Validity and Reliability

Validity is concerned with the accuracy, meaningfulness and credibility of the research project as a whole. To ensure validity, a research instrument must measure what it is supposed to measure. Due to the nature of the study that it depends on perceptions, attitudes and experiences of individuals, the study is not likely to yield the same result when replicated. However, respondents who are knowledgeable and experienced about study objectives were involved in this study in order to improve the dependability of the results. To enhance the validity of the survey instruments, a pilot study was conducted using twenty three (23) representatives from the sample. Feedback from the pilot-study respondents regarding the content, scope, question structure, and response scales was solicited and used to make improvements to the survey questionnaire.

Reliability refers whether the data collection technique, and analytic procedure would reproduce consistent finding if they were repeated on another occasion or if they were replicated by another researchers. For this study the Cronbach’s alpha. Cronbach’s alpha is a statistic commonly quoted by authors to demonstrate that tests and scales that have been constructed or adopted for research projects are fit for purpose(“National Research Council Committee on Scientific

Principles for Educational Research," 2002). The Cronbach's alpha result for this study expressed in table 3-2 and 3-3 below.

Table 3-2 Cronbach's alpha result for reliability test to the challenging variables

Case Processing Summary				Reliability Statistics	
		N	%	Cronbach's Alpha	N of Items
Cases	Valid	211	100.0	.728	20
	Excluded[a]	0	.0		
	Total	211	100.0		
a. Listwise deletion based on all variables in the procedure.					

Note: The Cronbach's alpha result for the challenges of TT in prefab technology was 0.728>0.7 which shows acceptable internal consistency across the whole questionnaire.

Table 3-3 Cronbach's alpha result for reliability test to the channels variables

Case Processing Summary				Reliability Statistics	
		N	%	Cronbach's Alpha	N of Items
Cases	Valid	211	100.0	.778	7
	Excluded[a]	0	.0		
	Total	211	100.0		
a. Listwise deletion based on all variables in the procedure.					

Note: The Cronbach's alpha result for the channels of TT in prefab technology was 0.778>0.7 which shows acceptable internal consistency across the whole questionnaire.

3.6. Flow chart of research

The overall forecasted research structure is as shown in the figure below.

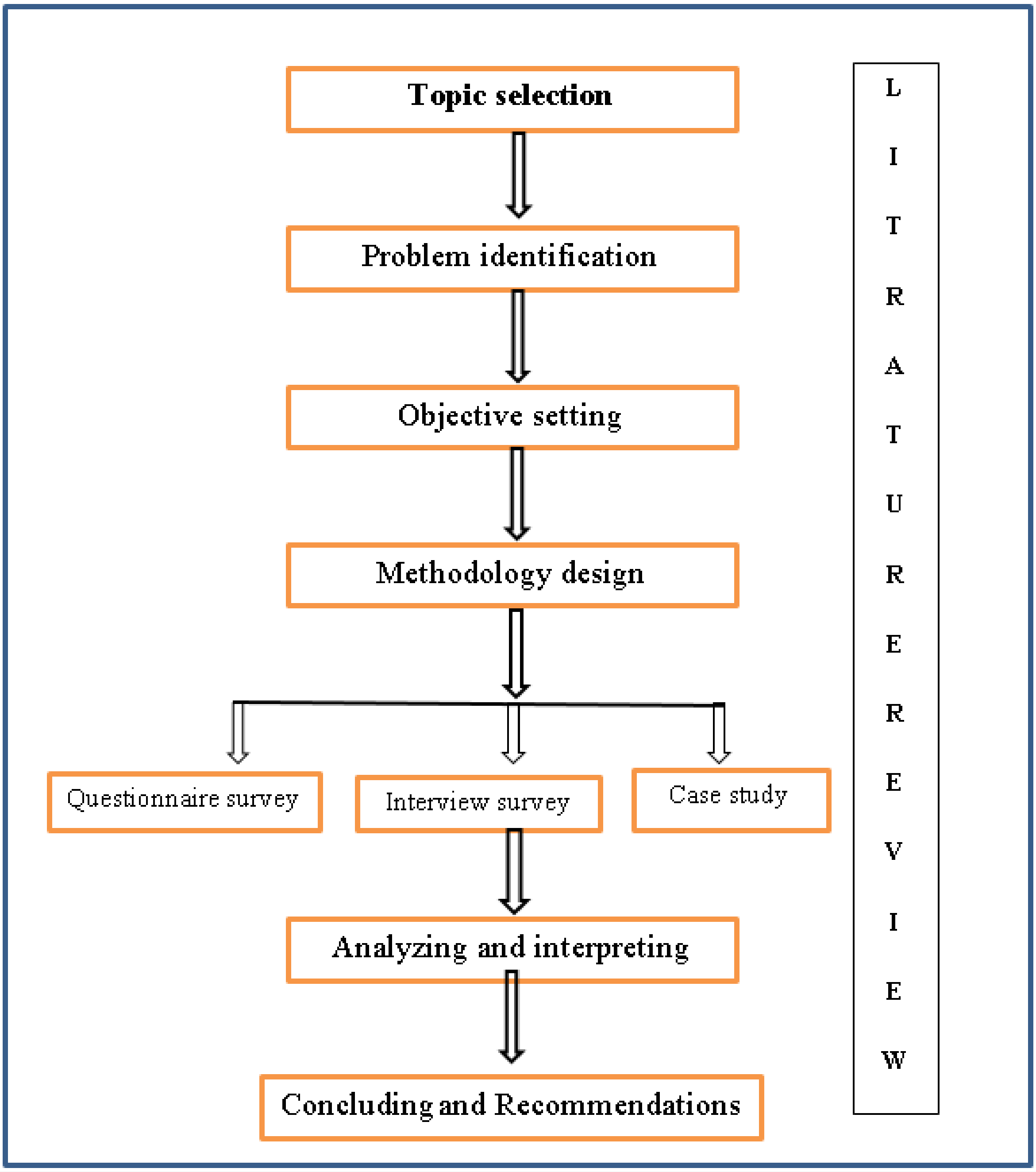

Figure 3.2 Overall flowchart of the study

4 RESULT ANALYSIS AND DISCUSSION

4.1. Introduction

The previous successive chapters were helping to reach research discussion and findings of the study. Hence, this chapter is fundamentally focused on the analysis of data discussion and presentation of the research findings. The presentation is done with the aid of graphs, pie charts, and tables. The data analysis was done using descriptive statistics. In calculating the relative importance index, all factors were given equal weight but depend on the respondents rating.

The total number of questionnaires which is distributed to purposively selected respondents were 346. Out of this questionnaire, 241 questionnaires were returned and the remaining 105 questionnaires were not returned due to respondents were not complete on time and the negative attitude of respondents towards the research. From 241 questionnaires returned, 30 questionnaires were rejected due to the fact that respondents answer is incomplete and not relevant for the analysis purpose. The rest of the questionnaires were used in the study. The return rate which is 69% implies that a very good workable questionnaire is found. The questionnaire sample is attached at appendix part of this document.

Table 4-1 Distribution and response rate of questionnaires

Respondents Companies	Distributed questionnaire	Returned questionnaire	Percentage returned (%)	Useable	Useable percentage
Construction companies	257	168	65%	156	61%
Others	89	73	82%	55	62%
Total	346	241	69%	211	61%

4.2. Respondents profile

As the population of the study was all construction stakeholders which have actively participating in the industry, and researchers and academicians were included to collect the perception of individuals. The following table and graphs show their specific organization and position on their organization.

4.2.1. Respondents organization

This is the characteristic of respondents and helps to know the proportion of respondents in terms of the organization in the construction industry. Therefore, their holding organization according to the questionnaire survey are illustrated in the figure 4.1 as follows

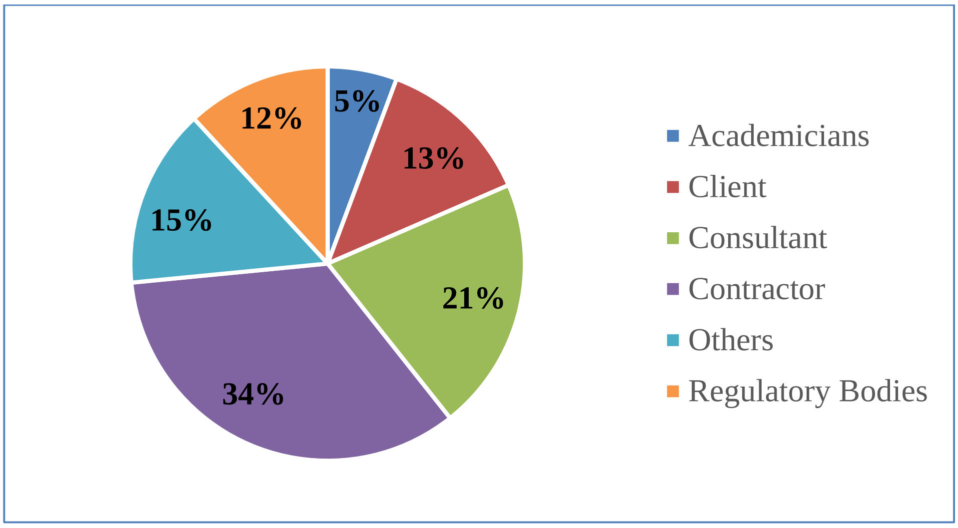

Figure 4.1 Organization of Respondents

As shown above 29% of respondents were contractors or working with contractors and the second most respondents were consultant office with 17%age. The list participant organization in this survey was the government body.

4.2.2. Position of respondents

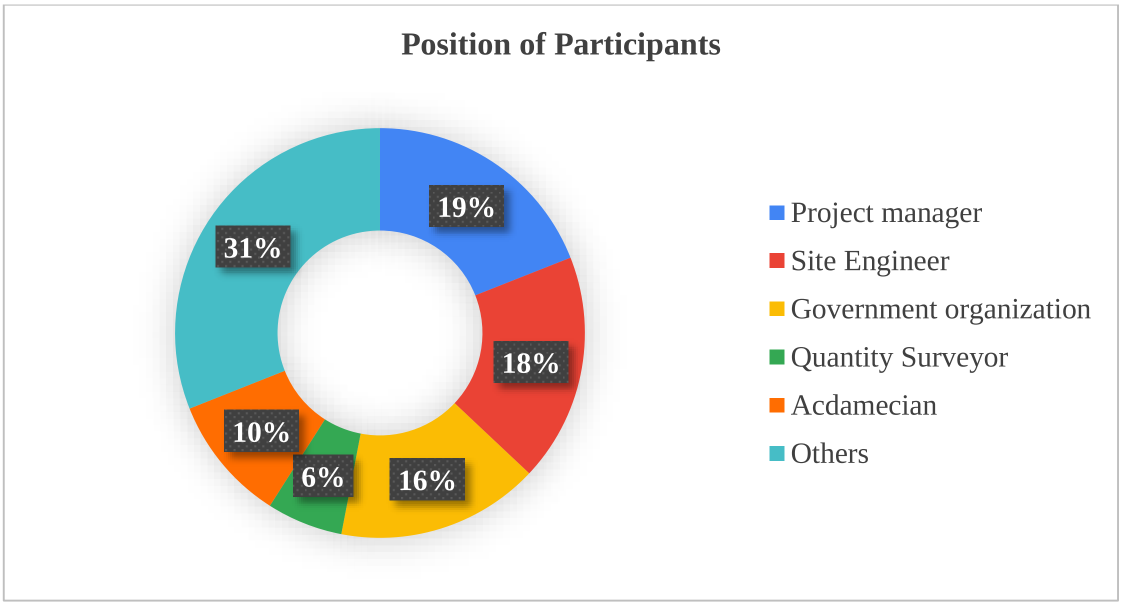

Figure 4.2 percentage of participant’s position in their organization

This is the characteristic of respondents and helps to know the proportion of respondents in terms of the position on their organization in the construction industry. Therefore, their holding positions according to the questionnaire survey are illustrated in figure 4.2 above. And, 31% of the participants was categorized as others (including construction manager, supervisor, marketing managers, and resident Engineer) and, 19% of the participants are working as project manager and 18% of the participants was site Engineers are the majority of the respondents.

4.2.3. Experience of respondents

The intent of this part of the background information was to ascertain the working experience of the respondents. And, the work experience of the respondent was surveyed by categorizing in to four groups as 0 to 5 years' experience, 6 to 10 years' experience, 11 to 15 years of experience and 16 years and above experience. The following figure shows the percentage of their experiences.

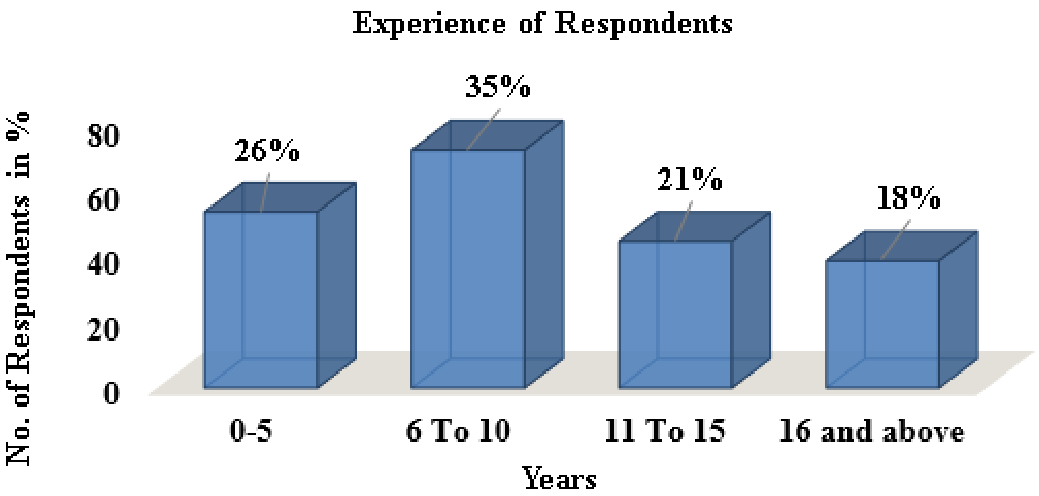

Figure 4.3 Experience of respondents

Based on the figure 4.3 the survey shows 35% of the respondent were have an experience of 6 to 10 years' experience which is the majority of the respondents. Meanwhile, the second one was 26% of respondent were has experience of 0 to 5 years experiences. And 21% & 18% were 11 to 15 years of experience and 16 and above years' experience respectively. The results give indications that respondent in this survey have reasonable experience and a plausible conclusion therefore is that the respondents are experienced in TT process.

4.2.4. Education background of respondents

The following figure shows the educational background of the respondents. From the graph, one can understand that the majority of respondents have completed BSc educational qualifications which are 42% of the sample population. This shows the BSc. Degree qualified workers or owners are no problem or motive to answer the given questionnaire. The second highest value was MSc. Degree and above-qualified respondents with 37%. Other respondents are 14%, and 7% diploma and other qualification respondents

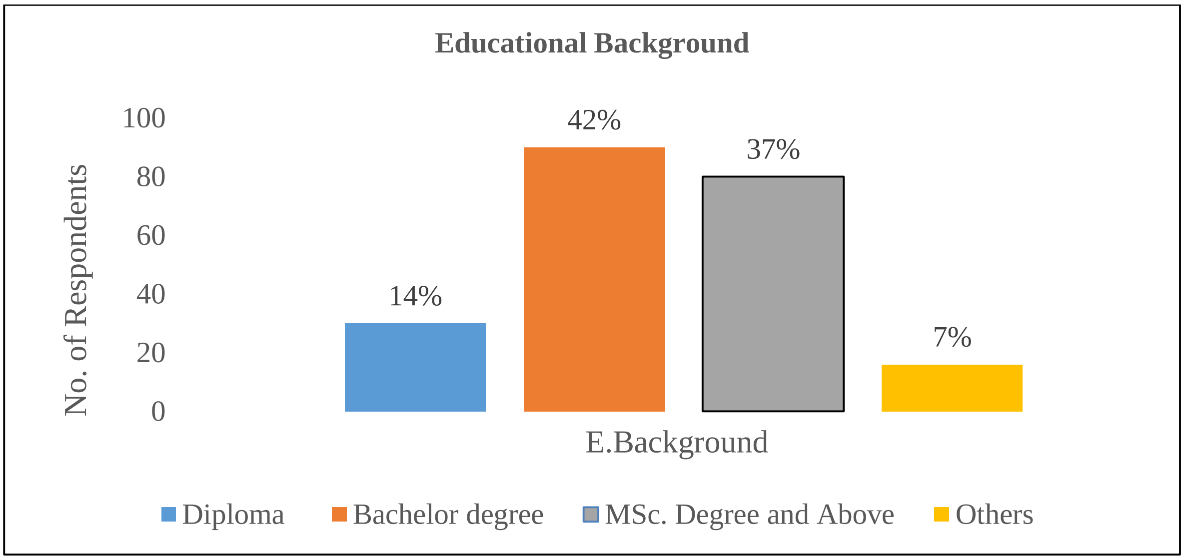

Figure 4.4. Educational Background of Respondents

4.3. Practice of prefabricated building technology in Ethiopia

4.3.1. Level of technology in Ethiopian construction industry

To assess the practice of prefabrication building construction in Ethiopia first assessing the current general construction technology was important. The researcher then used a questionnaire to compile individual views the level of technology in Ethiopia construction industry.

As you shown in the figure 4.5 below 39% of the respondent responses for the current level of technology was low level and 34% moderate level; and 12%, 11%, and 3% were very low, high, and very high respectively. From this result, the level of technology in the Ethiopian construction industry was at the lower level. The same to this, (Jakele, 2017) agreed that construction industry development in Ethiopia was going leisurely. Therefore the level of construction technology was at its lowest level.

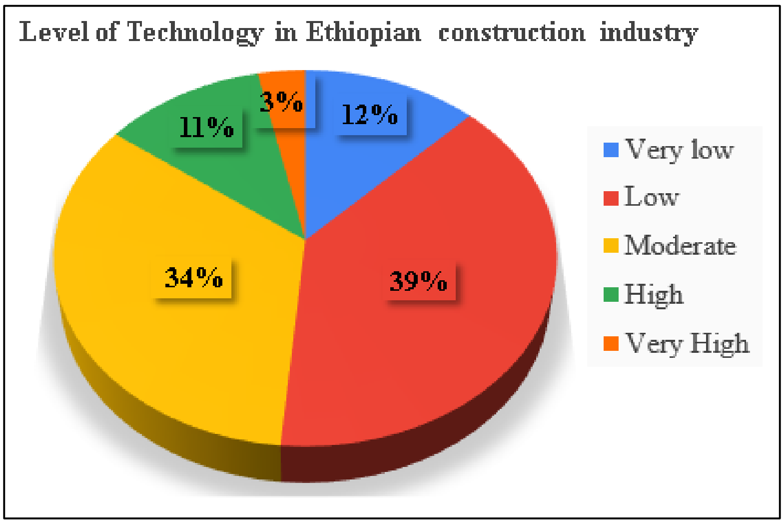

Figure 4.5. Current level of technology in Ethiopian construction industry

4.3.2. Needs of technology transferring in Ethiopian construction industry

The same to the above question; participant was asked to answer the need for technology transferring in the Ethiopian construction industry as yes or no question.

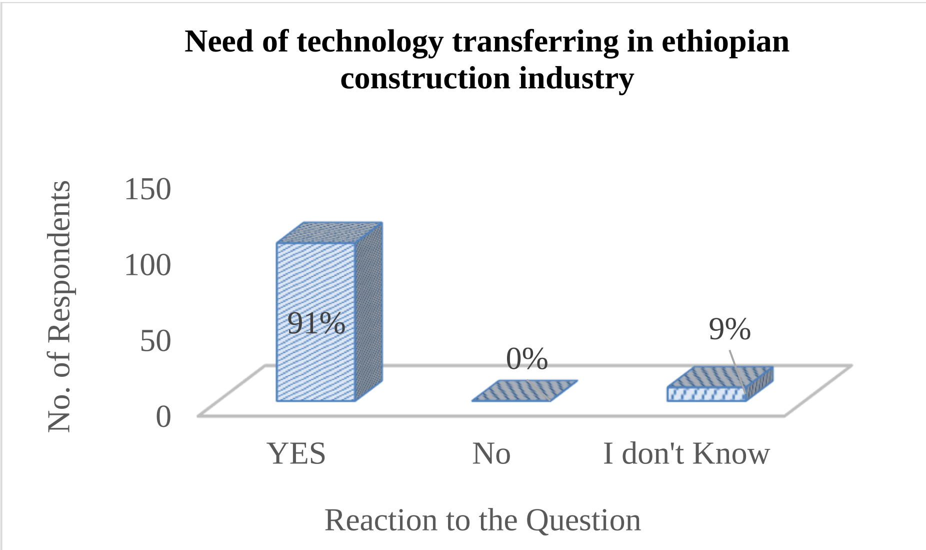

Figure 4.6. Need of technology transferring in Ethiopian CI

From figure 4.6 above the 91% of the respondent answered yes and the other 9% says no. At the same time, interviewee agreed Ethiopian construction industry need additional action. The level of technology in Ethiopian CI was at the infant stage and it needs to develop and adopt new techniques; this may be through transferring technology from others or improving and compiling to indigenous materials and techniques. The same to this, (Tesema, 2019) concluded that prefabricated construction in Ethiopian needs additional contribution from all stakeholders of the construction industry. As the mystery on the development of developed nation's construction industry was their high absorption capacity of new technology (Uusitalo & Lavikka, 2020). Therefore, working in technology transferring of prefabricated technology is crucial.

4.3.3. Practice of using prefabricated Building construction method

The following shows the percentage of respondent in their practicing of prefabricated building construction in Addis Ababa city.

Table 4-2 Result of respondent in practicing prefabricated building construction

Do you have any work experience in using prefabricated Building construction method?			
Answer	Yes	No	Total
No. of Respondents	52	159	211
Percentage (%)	24.6%	75.4%	100%

From table 4-2, only 24.6% of the participant was has been the experience of prefabricated building construction technology, the other 75.4% of the respondent was not practiced any kind of prefabricated element. From the interview the result shows most of the participant has an experience in prefab technology. And, based on the interviewee result practically the practice of prefabrication technology in Ethiopia is close to non-existence. Tessera, (2020) also concluded the practice of prefab technology in Ethiopia was non-presence. From the literature Ghana and South Africa was going foreward currently in using prefab technology and, solving housing problem in their country(Essienyi, 2011).

4.3.4. Current usage of prefabricated techniques in the sub-sectors of construction

Respondents were asked to rate the current usage of prefabricated building techniques in various sub- sectors (as shown in the table 4-3 below) of the construction projects.

Table 4-3 Representation of respondents rating for current use of prefabricated technology in building sub sectors

Name of the subsector	Very low usage	Low usage	Average usage	High usage	Very high usage
Low cost housing	14	67	102	21	7
Office Buildings	98	106	7	0	0
Public Buildings	56	85	42	14	4
Hotels and restaurant's	123	68	20	0	0
Private building	133	75	3	0	0
Factories/Warehouses/ Industrial Buildings	16	45	78	42	30
Health and Educational Institutions	92	89	15	5	0

According to the current responses, prefabricated building techniques are highly used in warehouses/industrial buildings 42 respondents say high usage and 30 respondents says very high usage, and low cost housing was 21 high usage and 7 very high usage which is the second highest used building sector. At the same time, 133 participants expressed the fact that prefabricated building techniques are at very low usage in private housing sector and hotels and restaurant was the second least in using of prefabricated building technique when 123 of participant answered very low usage. The result implies, the participation of privet builder in using prefab in too low. And also, (Tessera, 2020) on his study the practice of prefabricated building was most comment in industrial buildings and government housing projects. At the same time in Nigeria prefabricated building technology was more practiced in public building like schools, health centers and offices(Adindu et al., 2020).

4.3.5. Practice of using prefab element

Participants were asked which type of prefab element was most experienced or experiencing. As discussed in the literature there are seven prefab elements most commonly using elements in Ethiopia. Depend on this participants were asked to answer which type of prefab element was

Never Tried (NT), Tried but Discontinued (TD), and when they are Currently Using (CU); and the following result was figured.

Table 4-4 Result of respondents for their practice of most common prefab elements

Prefab element	Currently Using	Tried but Discontinued	Never tried
Panelized wall	27%	17%	56%
Precast concrete frames and blocks	34%	13%	53%
Light gauge steel frame	27%	14%	59%
Calcium silicate board	8%	14%	78%
Magnesium board	12%	20%	68%
Agro stone pane	26%	23%	51%
Warehouse steel shades Container	28%	8%	64%

From the above table 4-4 the result shows and the result was shown precast concrete frames and blocks was the most practicing prefab element which is transferred from former Yugoslavia by the government to solve housing problem. And gets the highest value of 34% of respondents are currently using, 13% of my respondents have experienced it before but currently stopped, and also the remaining 53% of my respondents have never tried it before. The result shows limitation in spreading the technology as well as in upgrading. The second most experienced and currently experiencing prefab element was the Agrostone panel which has the result of 24% currently using participant and 24% of the have experienced it before 52% of my respondents are never tried it before which is the lowest value from the other types of prefab elements. The third most experienced prefab element was panelized walls 26% of the participant was currently using, 18% percent of the respondent has practiced it before, and 56% of participant has never tried it before. The fourth one most experienced element was warehouses, shades, and containers are practiced with the result of 29% of the respondent was answering there were practicing currently, 8% of the respondent has tried it before but currently stopped working with it, and the remaining 63% of the respondents have neither practiced before not using it now. The fifth one practiced prefab element was Light gauge steel frame with the result of 27%,11% and 62% of the respondent was currently practicing it, practiced it before but stopped using it now and never tried it before respectively. According to respondent Magnesium board and calcium boards are the least practiced elements used as prefab elements. 70% of the respondent has not practiced magnesium board, but only 10% of the respondent was currently using magnesium board as prefab element, and the remaining 20% was practiced it before and stopped now. Calcium board was practicing only by 8% of the participants and 79% of the participant has neither used it before nor using now, and the remaining 13% was practiced it previously in their construction company.

Figure 4.7 A) Ribbed slab practice in Addis Ababa condominium housing construction B) Precast beams in Addis Ababa condominium housings

The result shows precast frames element was most experienced in a school building, house building especially in Addis Ababa city in the condominium buildings. Precast beams and ribbed slabs manufactured off site then constructing with cast in place construction. As the interviewee said, no formwork is required to support the ribbed slab, when compared to solid slab, this method saved cost of formwork as result of this, it reduce significant amount of the project cost. The GTZ was supporting in guidance to use prefab elements such as like this. The integrated housing development program was collaborated with small and medium enterprises in producing precast frames and blocks by subsiding by the government. However, this practice was limited only in Addis Ababa and doesn't spread throughout the country; the reason why not spread over the whole country was discussed on the second objective of this study. At the same time, the

Agrostone panel was introduced from China to minimize the cost of building and reducing the time by producing 3meter height and 60cm in width in one panel. And easy to erection and can be produced by semi-skilled laborers. This type of prefab element was practiced in most of the regions of the federal democratic republic of Ethiopia. But there is a shortage of awareness on the user because as the factory was owned by the government there was a shortage of advertising and initiation on the product. Panelized walls are products of timber and steel which are used in wall, floor, doors, and window construction most of the time. Related to this the (SICU, 2017) studied the practice of penalized wall was restricted due to the shortage of timber in East African countries. When do you come to the least practiced prefab elements calcium board was have the highest percentage of a non-practicing element. According to the participant the reason behind non-practicing was a shortage of producer's in the local market and a lower supply range; and also most of the time this board used as decorative, finishing material, and ceiling board therefore it makes it expensive.

4.3.6. Source the prefabricated technology

For the elements in 4.3.4 the investigator tried to find the influence of available source or initiator for using prefab elements help in finding how they adopt prefabricated building construction technique. The following table shows the result of respondent how they get prefab technology.

Table 4-5 Rank of the source for prefab element

S.No	Source	Mean	RII	Rank
1	Government institution sources	3.69	0.739	1
2	Small firms collaborated with your firm	3.68	0.736	2
3	Supplier	3.24	0.647	3
4	Manufacturer	3.16	0.632	4
5	Customers initiation	2.90	0.58	5
6	Large firms collaborated with your firm	2.87	0.575	6
7	C. Architects or Engineers	2.83	0.566	7
8	Own worker innovation	2.31	0.461	8
9	Universities and other research centers	1.99	0.398	9

The result of the respondent from the survey shows government institution was the highest initiator in using the prefab elements in building construction with the mean value of 3.69 and 0.739 relative important index (RII). At the same time, from the interview the source of prefabricated building construction shows government highly participated in practicing prefab elements by producing concrete precast elements like precast beams and column, ribbed slabs and precast stairs; as well as the Agrostone production center was all owned only by the federal and regional governments. The other government owned source of prefab element was Ministry of National Defense. Defense Construction Materials Production Enterprise (DCMME) with the mission of To Produce Prefabricated House Elements. (Tesema, 2019) studied on prefabricated construction of National Defense Housing Projects in Addis Ababa and he concluded the first initiator of the technology was the government. The second available sources of prefab element was small firm collaborated with the organization (micro and small enterprises) which has the value of 3.68 mean value and 0.736 RII. The third initiator or source of prefab element in Ethiopia was the suppliers with the result of 3.24 mean and 0.647 RII; the interview result shows most of the warehouse and shads for industries was imported by the supplier from foreign countries therefore the suppliers ranked at the third level as source for prefab element. Manufacturers was the fourth source of prefab product in Ethiopia with the result of 3.16 mean value and 0.632 RII value. Customers' initiation was the fifth source with 2.90 mean value and, 0.58 RII value. Large firms collaborated with construction company was the sixth source of prefab element with 2.87 mean value 0.575 RII value. Construction Architects or Engineers are the seventh sources of prefab elements with 2.83 mean value and 0.566 RII value from this the capacity of architectures in innovating new technology and upgrading adopting existing technologies was limited. Innovation by own worker at the constructor company was ranked at eighth from the given nine (9) sources with the mean value of 2.31 and 0.461 RII values. Universities and other research centers are the last ranked source in adopting prefab technology with the value of 1.99 mean and 0.398 RII value. The result shows universities and research centers has a little contribution in initiating adoption of prefab elements. Depends on the whole result, the source of prefab element was dominated only by the government, micro and small enterprises, and suppliers. Additional work was needed on research centers and universities to conduct research and studies on new technologies.

4.4. Challenges of for transfer, diffusion and implementation of prefab technology

Participant was asked to answer if prefabricated building technology was adopted and diffused effectively in Addis Ababa. The answer shows 92% percent of respondents says prefabricated building technology was not adopted and diffused effectively and the remaining 8% percent of respondent was answered I don’t know. This shows prefabricated building technology was not adopted and diffused in Ethiopia. From Geleta (2019) the status of prefabricated building in Addis Ababa shows at low stage, but when compared with other area of the country the practice is higher than. The following table shows the result of participant.

Table 4-6 Adoption and diffusion of prefabricated building

Answer	Frequency	percentage
Yes	1	0.0047%
No	194	92%
I don't Know	16	8%
Total	211	100%

4.4.1. Stage of failures in transferring and diffusion of prefabricated building

Similarly, the respondents were asked to answer in which stage was failed transferring and diffusion of prefabricated building technology. Scaling was: Very low=**1**, Low=**2**, Moderate=**3**, High=**4** and Very High=**5** From the literature technology transferring was have four main stages acquisition/selection of technology, technology absorption or implementation, technology adaption or integration and Technology improvement.

Table 4-7 stages of failures in adopting prefabricated buildings

Stages	Acquisition/selection of technology	Technology absorption/implementation	Technology adaption/integration	Technology improvement
N	194	194	194	194
Mean	2.88	3.84	4.27	4.48

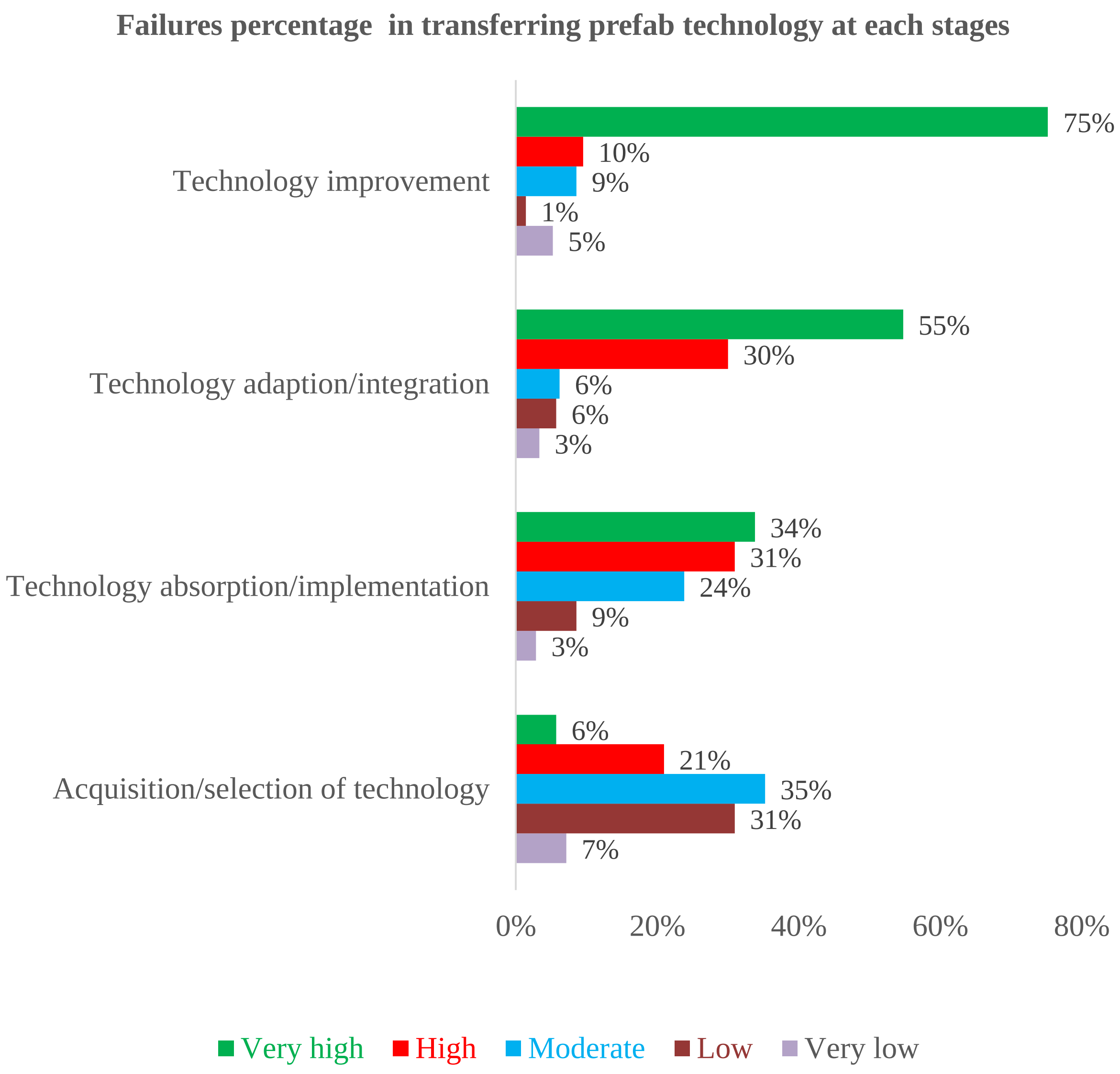

Figure 4.8 degree of failure in transferring prefabricated technology at each stage of TT

From the above table and figure someone can be drawn the transferring of prefabricated building technology was failed in the improvement stage of TT. The result shows technology improvement failures shows the highest mean value which is 4.48 and 75 % of the respondent answered transferring of prefabricated building was failed very highly at this stage. And at the stage of technology adoption or integration the survey shows 55% of respondent was answered very highly failed at this stage, and the mean value for this stage was 4.27. Technology absorption and implementation stage shows 3.84 mean value and 34% of participant was answered very highly failed at this stage and 31% of participant answered highly failed. The selection of technology shows 2.88 mean value and 6% of the respondent answered transferring of prefab technology at this stage was very highly failed and 21% of the respondent answered highly failed, and 35% of the respondent answered moderately failed and 31 % of the respondent says low degree of failures in transferring the prefabricated technology. Similar to this all the interviewee agreed in Ethiopia there was a plan to transfer technology and expedited only at the first time of introducing, however there was limited capacity of adoption and improvement of the technology consistently. On the other hand, the case study shows there were a good trying in selecting technologies and to solve shortage of housing, however initial financial funds and lack of expertise was impending the expanding and development of prefabricated technology.

From this result the transfer of prefabricated building technology was failed very highly at the implementation and improvement of transferred technology, and at the absorption stage the technology was failed highly also at the selection stage shows average result. And also, (Gutema B., 1998) on his research studied the transferring of prefabricated building technology was started in 1984 but, its diffusion and development was limited on government construction projects. According to (El-Abidi, 2014 & Gatew, 2011) the policy of technology transferring and improving in developing countries was not beyond plan or one time shopping practice. Starting from absorption technology transfer need additional contribution by all construction industry participant.

4.4.2. Factors challenging transferring and diffusion of Prefabricated Building Technology

It was deemed to identify factors challenging transferring and diffusion of prefabricated building technology in Ethiopia. And the following twenty (20) factors challenging technology transferring was drawn from the literature review and surveyed from the participant. This table illustrates the findings obtained from the data analysis of the questionnaire survey. The results reveal that the identified 20 factors are the challenges for diffusion and implementation and that none of the respondents proposed any new factors.

Table 4-8 challenging factors for transferring of prefabricated building technology

S.No	Factors challenging transferring and diffusion of Prefabricated Building Technology	Mean	Sig. (2-tailed)	Rank
1	Limited awareness, trust, or acceptance on its suitability	4.41	.000	1

2	High initial cost and limited financial fund option	4.32	.000	2
3	Insufficient funds for R&D	4.27	.000	3
4	Shortage of infrastructure to utilize prefabricated construction method	4.18	.000	4
5	Unavailability of qualified experts on prefabricated building	4.16	.000	5
6	Limited enforcement of prefabricated construction approach requirements	4.09	.000	6
7	Lack of collaboration and limited knowledge sharing during subcontracting	4.06	.000	7
8	Lack of stake holder participation	4.05	.000	8
9	Limited use of information technology among construction firms	4.04	.000	9
10	Inability to select and manage the technology	3.97	.000	10
11	Lack of standardization and absence of guideline for the method	3.94	.000	11
12	Lack of support from manufacturers and suppliers for new products	3.92	.000	12
13	Lack of policy incentive such as tax reduction	3.86	.000	13
14	Inadequate feasibility study	3.73	.001	14
15	Lack of Regulatory mechanism	3.66	.020	15
16	Incorrect marketing strategy	2.96	.565	16
17	Availability of low wages of laborers	2.94	.478	17
18	Cultural difference	2.90	.806	18
19	Government Policy problems hinder to transfer new technology	2.84	.064	19
20	Language barriers	2.69	.056	20

Twenty (20) statements relating the challenges of transferring and implementation of prefabricated building construction technologies was listed and presented in Table above. Their corresponded mean result was listed and ranked according to the mean value. For the discussion using one sample T-test method fifteen (15) factors are identified as important variables, and the discussed below. The confidence interval of the difference was 95%, and the assumed test value or mean of population was the three (3). The significance result from SPSS as compared to the test value of 3 which is neutral tell the researchers how relatively important of these variables. From table 4-6 above the results show that fifteen variables,(lack of policy Intensive such as tax reduction, lack of Regulatory Mechanism lack of Collaboration and limited knowledge sharing during Subcontracting, insufficient funds for R&D, unavailability of qualified experts on prefabricated building construction technique, shortage of infrastructure to utilized prefabrication, inadequate feasibility study, limited awareness on the purpose of prefabrication construction method, limited enforcement of prefabricated construction approach requirements, absence of guideline for the method and standardization, inability to select and manage the technology, high initial cost and limited financial option, lack of stake holder participation, limited use of information technology among construction firms, and lack of support from manufacturers and suppliers for new products shows) shows <0.05 significance result, which means which mean the respondents view these variables more important. To supplement the survey, interviews were conducted. Many of the respondent agreed on lack of participation of stake holders and high initial cost and limited fund option are the most important variable to consider in challenging transferring and sustaining the technology.

With regard to other five variables (availability of low wage laborers, government policy problems hinder to transfer new technology, incorrect marketing strategy, cultural difference, and language barriers) the respondents express that these are less important when their significance result was >0.05. This would suggest that these variables are less important on challenging transferring of prefabricated building technology and expanding across the country.

Limited awareness, trust, or acceptance on its suitability was the first ranked challenging factor in transferring and diffusion prefabricated building technology with mean value of 4.41 value. As the same time from the interview most of the participant agreed there was a low participation of construction stakeholders on transferring of prefabricated building technology and adoption. In the interview, result shows lack of stakeholder participation was the most common identified challenging factor in transferring the technology. When we came to the case study the higher initial cost was the main challenging factor to transfer and adapt the technology. The same to this, (Essienyi, 2011) in Ghana, and (Adindu et al., 2020) in Nigeria identified that; the main challenging factor in adopting and development of prefabricated building was low acceptability of the technology by the user. In Japan also, during the introduction time of prefabricated technology shortage of awareness hindered the development of prefabricated technology (Yashiro, 2001).

High initial cost and limited financial fund option: becomes the second hindering factor to transfer and adopt the technology; with 4.32 mean value. There are substantial financial and process risks associated with a builder changing to a new system. The interview and case study result also shows this factor as the main challenging factor in spreading the technology; due to the hurdle to get loan from both governmental and private financial institutions. The high initial costs to establish a factory setting of any kind were seen as a disadvantage, especially compared to the minimal outlay required of traditional residential building start-ups (Tessera, 2020). Many are also unwilling to spend the additional resources required to prove that the new technology is important to solve the impediment in construction industry development. Local contractors are suffering with shortage of initial fund especially in developing countries (Osabutey, et. al, 2014). Therefore this result reinforce the initial cost of prefabricated technology and shortage of high initial cost was as the main challenging factor in transferring and implementing the technology.

Insufficient funds for R&D: the other challenging factor ranked as the third by the respondent was insufficient funds for research and development related to prefabricated building when compared to other sectors. The mean value for this factor was 4.27. The result from the interview shows that research helps in improvement the technology after transferred but in Ethiopia researches has low chance of application; and shortage of feasible and applicable research make failed transferred technology. (Abate, 2020) on his study, the researches done in Ethiopian higher education's was not concentrate to the industry. Yet, in developed countries like Japan, invested and collaborated their studies to the industry. Japan, invested high budget to researches in prefabricated technology to substitute the imported material with local one (Manley, 2019).

Shortage of infrastructure to utilize prefabricated construction method: also shortage of infrastructure was become the fourth challenging factor in diffusion of prefab technology with the result of 4.18 mean. In the interview the participant agreed that, infrastructure was an important criteria to expand prefabricated technology. However, the participant agreed that they do not think the shortage of infrastructure in Ethiopia was the major obstacle to adoption of the technology. The interviewee says "*in absence of prefabricated construction technology, how can we say shortage of infrastructure impede the technology*". Ofori, (2015) also identified that lack of infrastructure in developing counties hinder the access to prefabricated technology, whereas small grade contractors are not motivated to use the technology to minimize additional cost expense.

Unavailability of qualified expert on the technology: was also the fifth challenging factor diffusion prefabricated technology with a mean of 4.16. The case study one also shows lack of expertise in prefab technology in Ethiopia make difficult to expand the technology. On the literature also both the developed and developing countries are challenged in transferring and adoption of prefab technology due to unavailability of qualified expert (El-Abidi & Ghazalia, 2015, & Han. & Zhu 2017, and Ofari, 2015).

Limited enforcement of prefabricated construction approach requirements: becomes the 6^{th} challenging factor in transferring and diffusing prefabricated building technology with the mean value of 4.09. In Ethiopia there is no any mandatory rules and regulation to use prefabrication technology. Countries like Australia and Malaysia has regulated on their construction code that mandated building constrictors to use prefabricated techniques El-Abidi, et. al, 2019).

Lack of collaboration and limited knowledge sharing during subcontracting: the result also revealed mean value of 4.06 ranked as the 6^{th} challenging factor. During the interview the problem with subcontracting was the subcontracting party used the project only for temporary benefit only, but not sharing lasting experience from the contracting party. Ghanaian experience shows, foreign contractors participating in Ghana CI should to collaborate with local contractors to share their experience.

Lack of stake holder participation: the 8^{th} one was lack of cooperation among Construction companies' and participation is an obstacle to the transfer and expansion of technology. The result shows 4.05 mean value. On the other side, from the interview limited participation and need to introduce and expand new technology is limited on the private construction companies become the first challenging factor. As challenge to the technology transfer is the conservatism of the key participants in the project. In fact, the construction industry is very conservative. It cannot use the trial-and-error method for innovation because failures have grave consequences for public safety. An owner who will occupy the structure will not tolerate any unnecessary risk or potential liability caused by using a new technology.

Limited use of information technology among construction firms: was the 9th one challenging factor according to participant in transferring and diffusing of the technology with the result of mean4.04. In the case study shortage of information sharing platform was one of the main problem in transferring the technology by GTZ.

Inability to select and manage the technology: also the 10th challenging factor with the result of 3.97 mean in transferring and expansion of prefabricated technology.

Lack of standardization and absence of guideline for the method: is the other challenging factor ranked as the 11th with the mean value of 3.94. the absence of standard building parts size make difficult to use the technology when standardization make simple to produce mass product in a time and using one machinery.

Lack of support from manufacturers and suppliers for new products: as suppliers and manufacturers are working for profit introducing new technology create doubt in acceptance on the market. The result from the participant shows the 12th ranked factor with the result and, the mean value is 3.92.

Lack of policy incentive such as tax reduction: is challenging factor in transferring and diffusing prefabricated building technology. Lack of policy incentive was ranked at13th due to its mean index of 3.86.

Inadequate feasibility study: feasibility study helps in predetermining the adaptability, economically visibility and socially acceptance of one new technology. In this study in adequate feasibility study ranked 14th by scoring mean of 3.73.

Lack of Regulatory mechanism: was the 15th important variable in challenging transferring and sustaining of prefabricated technology with mean value of 3.66.

As shown on the table Incorrect marketing strategy, Availability of low wages of laborers, Cultural difference, Government Policy problems hinder to transfer new technology, Language barriers become the other challenging factors on transferring and expansion of prefabricated technology ranked 16th to 20th respectively according to their mean value.

Other factors was identified by the interviewee as challenging in transferring and diffusing of prefabricated technology; from those unwillingness of foreign contractors to teach and give trainings to the local employees especially the Chinese company directly deployed their own workers from china in technical works. Unable to stimulate the development of local technologies also the other challenging factor in improvement of prefabricated building technology; relating to shortage of funds for R&D and its limited application interviewee identified synchronize the available local resource with the technology.

The result of this study shows, the limited awareness, trust, or acceptance on its suitability, high initial cost and limited financial fund option and insufficient funds for R&D are the most challenging factors to the transfer and expanding of the technology.

4.5. Channels or mechanism of transferring prefabricated building

The following channels or mechanisms of technology transferring in construction industry was identified from the literature and used for the survey, when the participant asked to answer their agreement on the best channel to transfer the prefabricated building technology; when the scaling measurement was Strongly Disagree=1, Disagree =2, Neutral=3, Agree=4, and Strongly Agree=5and gotten the corresponding mean and RII value as shown on the following table.

Table 4-9 Result of channels for TT in prefabricated building technology

Channels	Mean	RII	Rank
Trainings	4.66	0.932	1
Sub-contracting	4.02	0.805	2
Research and Development (R&D) centers	3.99	0.797	3
Turnkey contracting (TKC)	3.98	0.795	4
Foreign Direct Investment (FDI)	3.93	0.785	5
Joint Venture (JV)	3.52	0.704	6
University and Industry Linkage	3.48	0.699	7

The result revealed that training and workshops for human resources in the industry become the first ranked channel or mode of transferring prefabricated technology with the mean value of 4.66 and RII of 0.932. The result shows consistence as the result on the practice was failed very highly at the improvement stage of the transferred technology. It revealed that the choice of channel of TT may be limited by various factors including government legislation, construction industry structure and competition of the technology on the market. According to the participant the second ranked channel was sub-contracting with the result of 4.02 mean and 0.805 RII value. As sub-contracting help in sharing experience small firms with experienced one this open way to adopt new technology performed by the large firms. Research and development (R&D) was the third ranked channel by the respondent with the 3.99 mean value and 0.797 RII value. This result also shows prefabricated technology can transferred and adopted by modifying and collaborating with local economic, social and geographical conditions. Therefore R&D is important channel for developing countries. More funds is needed in R&D to compound the technology with local materials and human resource capacities. Also Turnkey contracting become the fourth channel agreed by the participants with the mean value of 3.98, and RII value 0.795. Turnkey contracts was mechanism of TT because it involves a foreign organization undertaking the construction of a production facility and turns the key to a domestic firm or some other organization when the facility is ready for operation. In Ethiopia the participation of foreign company in building construction was limited only on high rise building, and not used this type of delivery method. Foreign direct investment become the fifth ranked channel according to participant agreements; with the result of 3.93 mean, and 0.785 of RII value. As the higher initial fund was one of the main challenging factor in transferring and diffusion of prefabricated technology foreign direct investment may consider as the best way in transferring and adopting the technology, however the result shows at the fifth by the respondents. Joint venture is the sixth channels according to the participant with the mean value 3.52 and RII value of 0.704. The last ranked from the seventh channels at seventh was university industry linkage with the 3.48 mean value and 0.699 RII value. Greater collaboration between industry and academia, notably in relation to influencing the design of training and qualifications, could enable the transfer of technology, however the respondent ranked at the last.

In conclusion to the channels or mechanisms of transferring prefabricated building technology the result of this study shows, training and subcontracting are the best first and second ranked channels in the questionnaire. And also, in the case study in field/job training was the common way of transferring in the prefabricated building technology, and the second case shows technologies was adapted from literature and research studies. However according to the interview, they agree that the participation of foreign companies will help solve the financial crisis and transfer new technologies from different countries. And in field training was the second agreed mechanism of transferring prefabricated building technology.

4.6. Case studies

Project name: The Addis Ababa 40/60 Housing Project

Project description: the 40/60 housing project was started in2004 at Addis Ababa with pilot projects at Bole/Gerji apartment buildings. Aiming at capacity building in overall of the housing project in the country and improve the life of 100milion slums in 2020. With collaboration with GTZ (Gesellschaft für Technische Zusammenarbeit) which is international cooperation enterprise for technical assistance supported by Germany government; and its goal is to enhance the capabilities of people, organizations and institutional structures in the partner countries and MH engineering introduced environmentally friendly and cost efficient construction materials (low cost housing project). Public Private Partnerships (PPP) between German and Ethiopian private sector organizations, facilitated by the German and Ethiopian public sector. While mean the GTZ has 80 research institutes, each of them having a TT department all across the world.

Introduced new technologies: Financially viable and technologically sound construction solutions on the basis of prefabricated elements have been demonstrated, applied , trained and multiplied to make the approach sustainable and replicable. Introduced new technologies are U-shaped block, same size as hollow block used for prefabrication of lintels and beams, Pre - fabricated slab system (beams and hollow blocks) no formwork required. The laborers working on the construction sites are introduced to new technologies, receiving systematic training on the job. This helps them in selling their labor force later on, at a higher price as well as multiplying the technology in their respective location. Manual is prepared and used as guide line for the construction of standardized building parts.

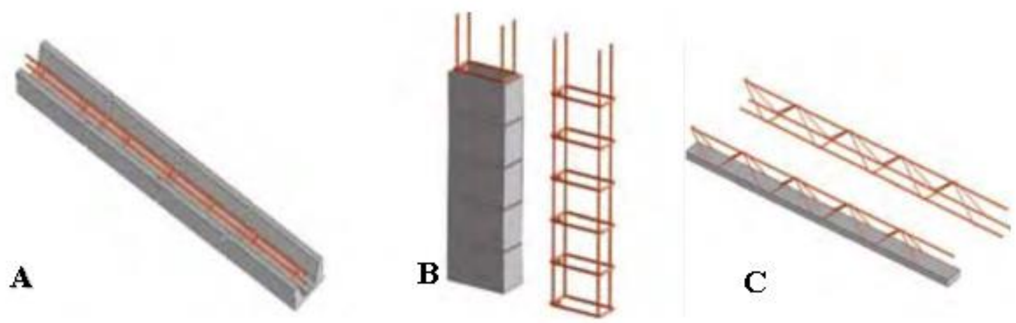

Figure 4.9. A) Precast lintel using U-shape HCB connecting with reinforcement B) precast HCB column and reinforcement C) precast beam using HCB and reinforcement

Challenges: As the Ethiopian construction sector is not yet ready for mass construction program there was a lot of challenging issues from those:

- Shortage of fabricated element manufacturers and suppliers
- Qualified contractors and sub-contractors as well as local prefabricated building expertise
- The trained skilled and semi-skilled laborers are not will to share their experience into the all corner of the country
- Communication platform was low in Ethiopian construction industry when comparing with other GTZ partners in Asia.

Channels: the GTZ for International Service (IS) cooperated with Ethiopian government to introduce new way of construction to solve the shortage of housing in Ethiopia. Training and capacity building was the way used to transfer new technologies to the local contractors, designers, academicians, small-scale and micro-scale enterprises, and other construction industry stakeholders.

To solve the financial shortage the Addis Ababa housing office which, collaborated in mortgage loan will be facilitated by the Commercial Bank of Ethiopia. On the other side the government of Ethiopia, allows foreign investors who can build more than 1,000 residential houses will be encouraged to take part in real estate development individually or in partnership.

Figure 4.10 Products of Agrostone for wall construction

Figure 4.11 Factory store constructed using Agrostone panel

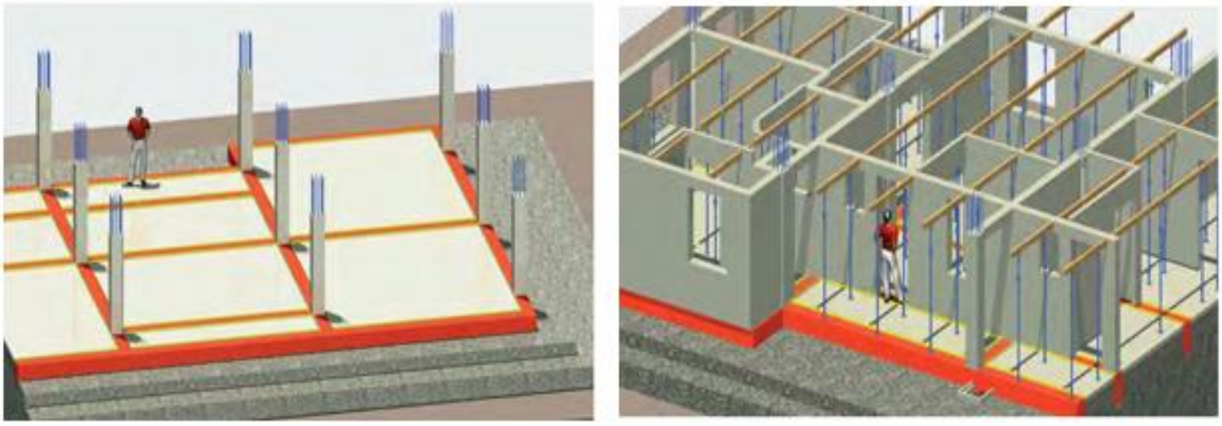

Figure 4.12 Left) Grade beam and Column Arc design Right) Temporary support for precast beam arc design by GTZ and MH engineering

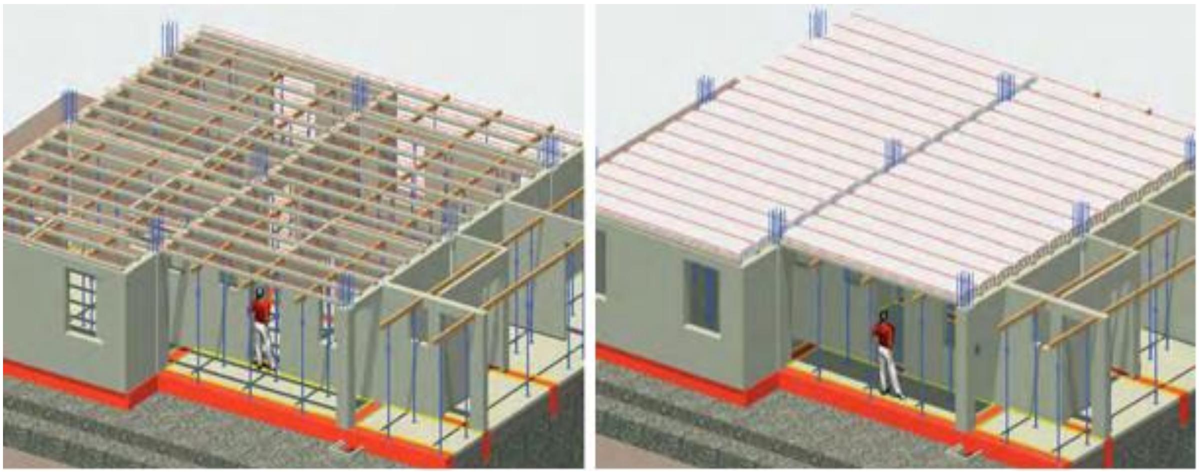

Figure 4.13 Left) Installation of precast beam design Right0 Installed precast beam and slab hallow blocks arc design GTZ and MH engineering

Case study 2.

Company name: Addis Prefab housing manufacturing industries

Establishment year: 2004 E.C.

Address: on the road from 22 mazoria to Bole medhanalem, worku building 2nd floor, Addis Ababa, Ethiopia

Brief of the company: Addis Prefab Houses Manufacturing Industries was a company established to construct prefabricated homes using light gauge steels (LGS) as structural elements and calcium silicate board as walling material. In addition to addressing the ever increasing housing demand in the country, the main aim of this project was to reduce the construction cost and time; as Ethiopian construction industry was suffering with delay in construction time and increment in costs. It is also established as Share Company with six members at its starting. This company was established with the aim of delivering innovative housing to fill huge gap between housing demand and supply on the operating environment. This was success by constructing residential and commercial buildings with the reduced construction period, time and standardized structural elements to produce in mass.

Construction method and materials adopted: The Construction methodologies of this company is introducing a revolutionary construction technology that reduces construction costs by 30 – 40% while at the same time building them 500% (Buildings) and 800% (Houses) faster by constructing structures which utilize Light Gauge Steel (LGS) structure frames typically clad with Calcium Silicate Boards (CSBs) which are indistinguishable from homes and buildings built using conventional materials and techniques.

Light gauge steel (LGS): is adopted from Australian innovators produced from metal sheet and used as structural element of a house. LGS is light in weight and high strength and treated using zinc alloy to protect rust.

Calcium silicate board: is non-compostable slighter material used as external wall and internal partition wall. Addis prefab housing selected this because of its availability of raw materials (95% of raw materials are available locally). The walling material was experienced highly in china and other Asian countries.

Practice learned from china shows G+2 homes are constructed within 24 hours, but Addis prefab planned to construct G+1 home within 15-20 days. The reason to delayed from the Chinese practice was to build up the practice on the society as home building take long period of using conventional construction method. During design Addis prefab used steel framing software and 3d steel detailing.

Challenges: the company imported production machineries from USA and received 53,000m^2 plot of land at Sendafa, Beke, however could not started operation due to shortage of finance. As the initial cost is high for the machineries and lease of land there was huge gap in budget to start operation. When the company asks for loan the government asks guarantee, and the private owned finance options doubted on its marketability. And then the company received initial payment from home buyers to facilitate the operation(Alemu, 2012).

As a solution the company tries to increase the shareholders, working with real estate developers (Access real estate and Hosea real estate plc.) as joint venture, and turns for foreign companies to participate on the business as last option. To solve the shortage of foreign currency Addis Prefab Houses Manufacturing Industries, Ethiopia signed a 15 million US dollar deal with Emirati Company Al Bahtawi General Building Equipment Trading, by supplying chemicals and steel coils for

However, the company could not construct homes as its planned on time due to this sued by the home buyers in 2015 and stopped its operation.

Figure 4.14 Left) high-tech steel framing machine Right) product of LGS

.

Figure 4.15 one of Addis prefab project at Bole beshale site

Source:(Www.adisprefab.com, 2015)

Figure 4.16 proposed Calcium Silicate Boards (CSBs) by Addis prefab manufacturing industry

5. CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

As the objective of this research was to investigate the practice and challenges of transferring prefabricated building technology as well as identifying best channels to transfer finally the following conclusions are drawn from the conducted study.

The finding showed that the level of construction technology in Ethiopia was at lower level. And the practice of prefabricated building technology in Ethiopia was almost to non-existent. 43% of the interviewee agreed the practice level of prefab technology in Ethiopia was at lowest stage. However, with some limited practice; the result of this study also shows the most comment practiced prefab element in Ethiopia was precast concrete elements and block. And 91% of the survey participant and 100% of interviewee was agreed on the need of technology transferring in to the construction industry. Also the initiator or facilitator for the prefabricated technology in Ethiopia shows based only on the shoulder of government.

From the assessed challenges in transferring prefab building technology the result of this study 92% percent of respondents says prefabricated building technology was not adopted and diffused effectively as it takes about four decades when it introduced in the building construction. Transferring of prefabricated building technology was failed in the improvement stage of TT, because imported technologies are not upgrading to indigenous resources and capacities. From the twenty (20) identified factors in challenging the transferring, adopting and sustaining the prefabricated technology fifteen (15) of them was significance. Limited awareness, trust, or acceptance on its suitability, high initial cost and limited financial fund option, insufficient funds for R&D, and shortage of infrastructure to utilize prefabricated construction method was ranked from first to fourth challenging factors in transferring, adopting and diffusing the technology respectively.

This study also surveyed the best channels for transferring of prefab technology by identifying from literature review and ranked based on the mean and RII values. The result shows training and work shop is the first ranked channel in transferring the technology. And following to training the second and third best channel was sub-contracting and working in research and development.

5.2. Recommendations

Based on the findings and conclusions made the researcher had forwarded the following recommendations:

The government should be to consider transferring prefabricated building technology as a viable solution to improve the quality, speed, and economy of upcoming building construction as well as to solve the shortage of housing in the country. Therefore, it is recommended to direct the stakeholders to participate in the technology transferring and expansion around all the corner of the country.

As the result shows the government was the leading actor in transferring and diffusing prefab technology in building technology, however, it is not enough depends on the current status of the practice additional concert effort of the government is needed in creating awareness on the society, facilitating the way for financial options for initial funds and working in cooperation the private sectors with other experienced foreign organizations on the field.

And also the effort of the government is not the only worried and blamable for the transferring and spreading out of the technology but the contribution of private sectors working in the construction industry also have a crucial role on its success; therefore participating on the sector in financing for research, machinery, and infrastructure is a good idea. Information sharing, providing experience sharing platform and collaboration of different professions (like the designer to contractors, contractors to contractors, designer to designers, academicians to industry, etc.) is looked-for.

Working in improvement of human resource capacity to lay a strong foundation for improved knowledge of prefabricated construction system and, solve the shortage of expertise in prefabricated technology by introducing in to curriculum in higher education institutions (universities and technical evaluation vocational training (TEVT)). As this was deepen the currently existing low level of knowledge of the construction industry professionals.

Providing mandatory sub-contracting to local contractors is necessary, when a contract was awarded for the foreign contractor was important. At the same time giving significant training and follow-up was for the sub-contractor to assimilate the technology to the required level.

Establishing research centers, linking higher institutions community with the industry, and collaborated with experienced abroad institutions to train local expertise was recommended.

However, most developing countries lack the domestic capacity to select, acquire and adapt imported technologies to their advantage and, finally, ensure their effective diffusion in the domestic industry. Such capacity can be built only with the concerted efforts of government, the industry and the professional bodies in the country, together with the support of the international community.

REFERENCES

Adindu, C. C., Yisa, S. N., Yusuf, S. O., Makinde, J. K., & Kamilu, A. M. (2020). Knowledge, adoption, prospects and challenges of prefabricated construction method in Nigeria – An empirical study of North Central Geo-Political Zone.

Aigbavboa, C., Aghimien, D., & Ntso, Y. (2018). Prefabrication in the South African Construction Industry – Challenges and Solutions. (2012), 1248–1254.

Alemu, F. (2012). History of Adiss prefab manufacturing industry. Retrieved February 9, 2021, from www.addisprefab.com

Ali, M. M. (2009). *Design and Development of Cost Efficient Houses The challenges and prospects of Affordability*. 1–20.

Almutairi, Y. (2015). *The University of Salford College of Science & Technology School of the Built Environment Development of Implementation Strategies for Offsite Construction Techniques in the Kingdom of Saudi Arabia*. (September).

Amaratunga, R. D. G., Shanmugam, M., & Rameezdeen, R. (2005). Transfer of technology in construction: Absorption capacity and internalization. *5th International Postgraduate Conference in the Built and Human Environment*. Retrieved from http://usir.salford.ac.uk/9937/

Auti, S. D., & Patil, J. R. (2019). Prefabrication Technology-A Promising Alternative in Construction Industry. *International Journal of Science and Research, 8*(8), 240–244.

Ayalew, T., Dakhli, Z., & Lafhaj, Z. (2016). Assessment on Performance and Challenges of Ethiopian Construction Industry. *2*(11), 1–11.

Baghchesaraei, A., Kaptan, M. V., & Baghchesaraei, O. R. (2015). Using prefabrication systems in building construction. International Journal of Applied Engineering Research, 10(24).

Bakar, A. H. A., & Tufail, M. A. (2012). Transforming capability of indigenous contractors through technology transfer: A Malaysia experience. World Applied Sciences Journal, 16(10), 1450–1461.

C. Goodier, A. G. (2007). Future opportunities for offsite in the UK. Construction Management and Economics. 25, 585–595.

Carrillo, P. (2006). Technology transfer : A survey of international construction companies Technology transfer : A survey of international construction companies. (November 2014), 37–41.

Cavell, C. T. K. M. P. E. H. M. (2014). *T*he Diffusion of Innovation in the Residential Building Industry.

Chane, K. B. (2017). Precast Construction in Ethiopia - An In-Depth Look at the PBPPE Precast Plant University,. Addis Ababa University: Addis Ababa.

Correia, A. L., & Murtinho, V. (2012). Housing prefabrication : Background for a conceptual development of the architectural project. (January).

Dave, M., Watson, B., & Prasad, D. (2017). Performance and perception in prefab housing: an exploratory industry survey on sustainability and affordability. *180*, 676–686.

Devapriya, K. A. K. G. And S. (2014). Technology transfer through subcontracting in developing countries. (December 2014), 37–41.

Dimitrijevic, R., & Jovancov, S. (2000). Transfer of the ims building technology into developing countries.

Dinku, A. (2017). Building industrialization, Agrostone production in Ethiopia ppt.

El-Abidi, K. M. ., Ghazali, Mohamed, F. ., & Azman, M. N. . (2014). Managing Transformation : A Focus on Prefabricated Building in the Libyan Construction Industry. CIB Internation Conference on Construction in a Changing World , 4th-7th May 2014, Heritance Kandalama, Sri Lanka, (April).

El-abidi, K. M. A., Abas, N. F., Ofori, G., Akmam, S., Zakaria, S., & Mannan, A. (2019). Identifying and evaluating critical success factors for industrialized building systems implementation : Malaysia Study. *Arabian Journal for Science and Engineering*.

El-abidi, K. M. A., & Ghazalia, F. E. M. (2015). Motivations and limitations of prefabricated building : An overview.

Elmer, U., & Meltofte, S. L. (2012). Overcoming Barriers to the Transfer and Diffusion of Climate Technologies.

Essienyi, J. F. K. And E. K. (2011). Prefabricated Housing, a solution for Ghana's Housing shortage. 1–76.

Fordjour, A. M. (2015). Development of a framework for technology transfer partnerships in the Ghanaian construction industry.

Gan, X., Chang, R., Zuo, J., Wen, T., & Zillante, G. (2018). Barriers to the transition towards off-site construction in China: An Interpretive structural modeling approach. Journal of Cleaner Production, 197, 8–18.

Gatew, G. (2011). Technology transfer as a vehicle for industrial development case of basic metals and Engineering industries.

Geleta, W. (2019). The status of modular building system in building construction industry : the case in addis ababa.

Girma, S., Chimdi, J., & Legese, A. M. (2020). Challenges of using prefabrication technology in Oromia. Journal of Civil Engineering, Science and Technolog*y, 11(1).*

Girmscheid, G. (2005). Industrialization in building construction production technology or management concept? Advancing facilities management and construction through innovation, Helsinki, Finland, 1, 427–441.

HAN, Y., & ZHU, W. (2017). The Development of Modular Building in China. *Destech Transactions on Engineering and Technology Research*, *2015*(ameme), 2012–2015.

Hong, J., Shen, G. Q., Li, Z., Zhang, B., & Zhang, W. (2018). Barriers to promoting prefabricated construction in China: A cost–benefit analysis.

Jaillon, L., & Poon, C. S. (2007). Advantages and limitations of precast concrete construction in high-rise buildings: Hong Kong case studies.

Jakele, W. (2017). Technology transferring in Construction Industry. *1st Construction Profession Week Magazine.Pdf*.

Kassu, A. G. (2012). *Ethiopia ' s STI Policy , Strategy and Updates National Innovation System of Ethiopia*.

Kebede, K. Y., & Mulder, K. F. (2008). Needs assessment and technology assessment: crucial steps in technology transfer to developing countries.

Kulić, M. M. And V. (2012). Prefabricated construction in former Yugoslavia . visual and aesthetic features and technology of prefabrication.

M A Mohd Amin, N H Abas, S Shahidan, M H Rahmat1, N A Suhaini, S. N. And R. A. R. (2017). A review on the current issues and barriers of Industrialised Building System (IBS) adoption in Malaysia ' s construction industry

Manley, K. (2019). Prefabricated housing firms in Japan and Sweden : Learning from leading Prefabricated housing firms in Japan and Sweden : Learning from leading countries.

Matsumura, S., Gondo, T., Sato, K., Morita, Y., & Eguchi, T. (2019). Technological developments of Japanese prefabricated housing in an early stage. *2*(1).

Ministry of Finance and Economic Development, F. D., & Ethiopia, R. Of. (2010). *Growth and Transformation Plan (2010/11 – 2014/15)*. 2010.

Mostafa, S., Dumrak, J., Chileshe, N., & Zuo, J. (2014). Offsite manufacturing in developing countries : current situation and opportunities. International Conference on Engineering, Project, and Production Management. Port Elizabeth, South Africa:

Mulu, Y. Z. (2018). *C*onstruction technology transfer for construction works in Ethiopia : the cases of grade one general contractors, (October).

Nadu, T. (2016). Present application ofresource management in prefabricated and in-situ construction. *3*(2).

National Research Council Committee on Scientific Principles for Educational Research, 2002. (2002). *Scientific Research in Education*.

Navaratnam, S., Ngo, T., Gunawardena, T., & Henderson, D. (2019). Performance review of prefabricated building systems and future research in Australia. *Buildings*.

Neilson, T. (2011). King of charcoal: Japanese create new life for dying industry. *Inwood Magazine*, *II*(96), 32–33.

Ngoenchuklin, C. (2014). Feasibility of implementing prefabricated U . S . products and methods for residential construction in Thailand.

Ngowi, A. (2002). Challenges facing construction industries in developing countries.

Ofori, G. (1990). Construction technology transfer : issues and options. (i).

Ofori, G. (2015). Nature of the Construction Industry, Its Needs and Its Development. *Journal of Construction in Developing Countries*, *20*(Universiti Sains Malaysia), 115–135.

Ofori, G. (2012). Construction industry development : role of technology transfer.

Omid Reza Baghchesaraei, Hossein Hosseini Lavasani, A. B. (2016). Behavior of prefabricated structures in developed and developing countries.

Osabutey, E. L. C., & Jackson, T. (2019). Technological forecasting & social change the impact on development of technology and knowledge transfer in Chinese MNEs in sub-saharan africa : the Ghanaian case. technological forecasting & social change.

Osabutey, E. L. C., Williams, K., & Debrah, Y. A. (2014). The potential for technology and knowledge transfers between foreign and local firms : A study of the construction industry in Ghana. *Journal of World Business*, *49*(4), 560–571.

Polat, G. (2010). Precast concrete systems in developing vs. Industrialized countries. *Journal of Civil Engineering and Management*, *16*(1), 85–94.

Ray, S. (2012). Technology transfer and technology policy in a developing country. *The Journal of Developing Areas*, *46*(2), 371–396.

Reza BaghchesaraeI, O., Hosseini Lavasani, H., & Baghchesaraei, A. (2016). Behavior of Prefabricated Structures in Developed and Developing Countries.

Shen, Q., Yu, Y., Hou, J., Wang, Q., Zhang, L., & Meng, X. (2017). The testing research on prefabricated building indoor thermal environment of earthquake disaster region.

Shukra, Z. A., Zhou, Y., & Wang, L. (2021). An adaptable conceptual model for construction technology transfer : The BRI in Africa , the case of Ethiopia.

Smith, R. E. (2009). History of Prefabrication : A Cultural Survey. *Proceedings of the Third International Congress on Construction History*, (May), 1355–1364.

Sustainable Incremental Construction Unit. (2017). Retrieved September 12, 2020, from https://www.appropedia.org/File:SICU_2013-09-28_sep_ws_0795_corr.JPG

Taffese, W. Z. (2012). Low-cost eco-friendly building material: A case study in Ethiopia. International Journal of Civil, Environmental, Structural, Construction and Architectural Engineering, 6(2), 183–187.

Talmazan,Y.(2020).RetrievedApril21,2021,from https://www.nbcnews.com/news/world/china-s-coronavirus-hospital-built-10-days-opens-its-doors-n1128531

Tam, V., & Tam, C. M. (2015). On prefabrication implementation for different project types and procurement methods in Hong Kong.

Tesema, H. T. (2019). The effect of prefabricated materials and equipment on cost efficiency of a building : the case of ministry of national defense housing projects in addis.

Tessera, B. M. (2020). *R*eview on the practicing of prefabricated building construction technology inEthiopia vs world experiences. 161–169.

Transfer, T., & Planning, U. (2016). *2016 / 17 Knowledge Sharing Program with Ethiopia :*

Udochukwu, I., Rong, D., Batool, H., & Ikechukwu, I. (2017). Technology transfer in construction and management : A Case for Nigeria Construction and Management Sectors. Management Science and Engineering, *11*(2), 28–34.

Uusitalo, P., & Lavikka, R. (2020). Technology transfer in the construction industry. The Journal of Technology Transfer.

Vukov, J. (2012). The influence of rapid industrialization on housing problerns in Yugoslavia.

Wang, W., Zhang, S., Su, Y., & Deng, X. (2019). An empirical analysis of the factors affecting the adoption and diffusion of GBTS in the construction market.

Www.adisprefab.com. (2015). Adis Prefab industry. Retrieved from www.adisprefab.com

Yashiro, T. (2001). A Japanese perspective on the decline of robust technologies and changing technological paradigms in housing construction: issues for construction management research. Construction Management and Economics, 19(3), 301–306.

APPENDIXES

Appendixes I: Definition of important terms

Adoption is the acceptance and continued use of a product, service, or idea. The adoption process refers to a series of mental and behavioral states that a person passes through leading to the adoption or rejection of a Technology(Cavell, 2014).

Absorption capacity is the ability of a firm to recognize the value of new external technology, assimilate it, and apply it to commercial ends

Diffusion is the spread of a Technology throughout a systematic way(Cavell, 2014).

Industrialization describes all pre work forms (prefabrication, preassembly and modularization), which relatively implies the use of fully integrated and automated project processes (Tam, 2015).

Modern method of construction (MMC) is used to collectively describe both offsite-based construction technologies and innovative onsite technologies in the construction industry

Modularization generally refers to pre constructing a complete system in a location away from that on the job site, and then transporting the completed system to the site(Dimitrijevic & Jovancov, 2000).

Off-site Construction includes preassembly, hybrid building systems, panelized building systems, and modular building systems(Mostafa et al., 2014).

Preassembly means “the manufacture and assembly of a complex unit comprising several components prior to the unit’s installation onsite” (Make = Fabricate + Assemble)(Polat, 2010).

Prefabrication is any component manufactured off-site, which is not considered as a complete system to be prefabricated. This is categorized as Zero-level “Basic Material” without pre installation assembly features(C. Goodier, 2007).

Appendixes II: Questionnaires for Research

Introduction

Dear Respondent: - This questionnaire is prepared to obtain information from key informants with structured questions. The information is required for the academic research entitled "*Challenges of Technology Transfer in Construction Industry: The Case of Prefab Elements in Building Construction in Addis Ababa city*." which is being conducted as partial fulfillment of MSc in construction technology and management. The questionnaire results and all the information obtained in the questionnaire will only be used for academic purposes. And all participants in the questionnaire and questionnaire data collation personnel will ensure that the information will not be leaked.

And the Specific Objectives of the study was:-

- ☞ To assess technology transfer practice in Construction Industry considering prefabricated building elements in Ethiopian construction industry:
- ☞ To identify the challenge in transferring and ensuring sustenance of prefabricated building elements in Ethiopian construction industry.
- ☞ To identify effective technology transfer mechanisms of prefabricated building construction.

Thank you very much for your time and cooperation, and looking forward to receiving your response!

ASGELE KIDU

Post graduate student, Construction technology and management
Hawassa University, Institute of Technology, Civil Engineering Department
Tel: +251932060785
Hawassa

Part I respondent profile

1. Respondent Background

1.1.Position of the respondent (Thick on the provided box)

Project Manager ☐ Academician ☐

Gov't organization ☐ Quantity Surveyor ☐

Site Engineer ☐ Supervisor ☐

Other (please specify) ________________

1.2.Respondent Organization (Thick on the provided box)

Contractor ☐ Client ☐

Consultant ☐ Regulatory ☐

Other (please specify) ________________

2. Experience and Educational Qualifications

2.1.Education level: (Thick on the provided box)

Diploma ☐

Bachelor degree ☐

MSc. Degree and Above ☐

Other (please specify) ________________

2.2.Working Experience in years: (Thick on the provided box)

1-5 ☐ 6-10 ☐

11-15 ☐ >15 ☐

Part II main questions

1. **Section one**: - General instructions for the practice of technology transfer practice in Ethiopian construction industry

Tick on the provided space based on your knowledge on level of Technology in Ethiopian Construction Industry (the options appear as: - Very low **(1**), Low (**2**), Moderate (**3**), High (**4**) and Very High (**5**); and the need for Technology Transfer (TT) the options are Yes or No; and also to measure the need of prefabricated building construction method options appear are: - Very Less Important (**1**) Less Important (**2**) Important (**3**) Highly Important (**4**) Very Highly Important (**5**); Yes or No for your practice; and the source of adopting new technology (the options appear as: - Very low (**1**), Low (**2**), Moderate (**3**), High (**4**) and Very High (**5**) in Ethiopian construction industry.

1.1.Level of Technology in Ethiopian Construction Industry					Need for TT in Ethiopia	
1	2	3	4	5	YES	NO

1.2.To what extent was prefabricated building construction is important in Ethiopian construction industry? Very Less Important=**1**, Less Important=**2**, Important=**3**, Highly Important=**4**,and Very Highly Important=**5**				
1	2	3	4	5

1.3.Do you have any practice in using prefabricated building construction technique?	
YES	NO

1.4.If your answer for No. 1.3 was **YES**; please indicate the status where your firm has Never Tried (1), Tried but Discontinued (2) or is Currently Using (3) each of the following prefabricated technology elements?			
Elements	1	2	3

a. Panelized wall			
b. Precast concrete frames and blocks			
c. Light gauge steel frame			
d. Calcium silicate board			
e. Magnesium board			
f. Agro stone panel			
g. Warehouses shades and Containers			

1.5. Please rate the sub-sectors below, in terms of usage of prefabricated technologies? If the scaling was very low usage=1 low usage=2 average usage=3 high usage=4 and, very high usage=5

Name of the subsector	1	2	3	4	5
1. Low cost housing					
2. Office Buildings					
3. Public Buildings					
4. Hotels and restaurant's					
5. Private building					
6. Factories/Warehouses/ Industrial Buildings					
7. Health and Educational Institutions					

1.6. According to your opinion rank the influence of available sources of adopting prefabrication building technology products, materials, and practice for your firm? If the scaling was: Not at all influential =1, Slightly influential =2, Somewhat influential =3, Very influential =4 and extremely influential =5

Source of the Technology	Measurement scale				
	1	2	3	4	5

A. Suppliers					
B. Manufacturers					
C. Architects or Engineers					
D. Universities and other research centers					
E. Own worker innovation					
F. Customers initiation					
G. Large firms collaborated with your firm					
H. Small firms collaborated with your firm					
I. Government institution sources					

2. **Section Two:** - In the table below, there are lists of stages in technology transferring in prefabricated building and possible challenges related to Technology Transfer in prefabricated building construction. Please show your choice by putting a mark (√) in the cells available. The options appear as: - Very low=1, Low=2, Moderate=3, High=4 and Very High=5

2.1. Do you think prefabricated building construction has been transferred, diffused and maintained sustainably in Ethiopian construction industry?	
YES	NO

2.2. If your answer for question No. **2.1** is **No** rate the extent of failure at different stage of adopting and transferring of prefabricated building construction technology was failed in Ethiopia? If the scaling was: Very low=**1**, Low=**2**, Moderate=**3**, High=**4** and Very High=**5**

Stages	Degree of impact				
	1	2	3	4	5
1. Acquisition/selection of technology					
2. Technology absorption/implementation					
3. Technology adaption/integration					
4. Technology improvement					

2.3. If your answer for No. 2.1 is **NO** please rank the degree of impact of the following parameters to diffuse and sustain prefabricated building technology? If the scaling was: Very low=1, Low=2, Moderate=3, High=4 and Very High=5

Problems during diffusion and sustaining of prefabricated building construction	Degree of impact				
	1	2	3	4	5
1. Lack of policy incentive such as tax reduction					
2. Lack of Regulatory mechanism					

3. Lack of collaboration and limited knowledge sharing during subcontracting					
4. Availability of low wages of laborers					
5. Insufficient funds for R&D					
6. Unavailability of qualified experts on prefabricated building					
7. Shortage of infrastructure to utilize prefabricated construction method					
8. Government Policy problems hinder to transfer new technology					
9. Inadequate feasibility study					
10. Limited market demand					
11. Lack of standardization and guideline for the method					
12. Inability to select and manage the technology					
13. High initial cost and limited financial option					
14. Limited awareness or acceptance on its suitability					
15. Cultural difference					
16. Language barriers					
17. Lack of stake holder participation					
18. Limited use of information technology among construction firms					
19. Limited enforcement of prefabricated construction approach requirements					
20. Lack of support from manufacturers and suppliers					

Section Three: - In the table below, there are lists of possible vehicles or channels related to Technology Transfer in prefabricated building construction. Please show your agreement level by putting a mark (√) in the cells available. The options appear as: - If the scaling was: - Strongly Disagree=1, Disagree =2, Neutral=3, Agree=4, and Strongly Agree=5

3.1. Rank the following vehicles according to their significance to transfer and adopt prefabricated building construction method.					
Vehicles	Degree of Impact				
	1	2	3	4	5
A. Foreign direct investment					
B. Sub-contracting					
C. Joint Venture					
D. Training and workshop					
E. University Industry linkage					
F. Research and Development centers					
G. Turnkey contracting					

Any comment or suggestion on the topic:---

Appendixes III: Questions for the semi-structured interview

Introduction

Dear interviewee: - This question is prepared to obtain information from key informants with semi-structured questions. The information is required for the academic research entitled "*Challenges of Technology Transfer in Construction Industry: The Case of Prefab Elements in Building Construction in Addis Ababa city*." which is being conducted as partial fulfillment of MSc in construction technology and management. The results and all the information obtained in the interview will only be used for academic purposes. And all participants on the interview personnel will ensure that the information will not be leaked.

And the Specific Objectives of the study was:-

- ☞ To assess technology transfer practice in Construction Industry considering prefabricated building elements in Ethiopian construction industry:
- ☞ To identify the challenge in transferring and ensuring sustenance of prefabricated building elements in Ethiopian construction industry.
- ☞ To identify effective technology transfer mechanisms of prefabricated building construction.

Thank you very much for your time and cooperation, and looking forward to receiving your response!

ASGELE KIDU

Post graduate student, Construction technology and management
Hawassa University, Institute of Technology, Civil Engineering Department
Tel: +251932060785
Hawassa

Interview questions

1. What look like the practice of prefabricated building technology in Ethiopia?

   Highest High

   Medium Low Lowest

2. Who do you think has the highest potential to improve the application of prefabricated structural elements in Ethiopia?

   Contractors Designers Clients

   Developers Government Researchers

3. What bottlenecks does your institution/company face in the prefabricated building technology transferring to the construction industry?

………………………………………………………………………………………………
………………………………………………………………………………………………
………………………………………………………………………………………………
………………………………………………………………………………………………
………………………………………………………………………………………………

4. What are the challenges to diffuse and adopt effectively prefabricated building construction in Ethiopian construction industry?

   ………………………………………………………………………………………………
   ………………………………………………………………………………………………
   ………………………………………………………………………………………………
   ……………………………………………………………………….................................

5. What are the best ways/mechanisms to transfer technology in prefabricated building construction?

   ………………………………………………………………………………………………
   ………………………………………………………………………………………………
   ………………………………………………………………………………………………
   ……………………………………………………………………….................................

6. What is your suggestion to improve construction technology transfer for the Ethiopian construction industry?

Appendixes VI: Figures show different practice of prefab technology

Figure 0.9 Prefab concrete blocks produced by England company in Ghana for school construction (source: Fordjour, 2015)

Figure 0.10 prefab container in Ethiopia (photo: researcher)

Figure 0.11 Market center constructed using metal sheet and steel frame at Gotera, Addis Ababa (photo: researcher)

Figure 0.12 Prefab steel frame G+5 office building in Addis Ababa

Figure 0.13 Metal sheet prefab building for Industry in Addis

Figure 0.14 Kotebe Metropolitan University 3-story office building constructed using precast concrete by ECWC (photo: AA construction office)