



**ADDIS ABABA UNIVERSITY**  
**ADDIS ABABA INSTITUTE OF TECHNOLOGY**  
**SCHOOL OF MECHANICAL AND INDUSTRIAL ENGINEERING**

A frame work to enhance the technology transfer for high rise building construction: A case study of CBE HQ project

---

By: Melat Solomon

Addis Ababa, Ethiopia

October 2018

A Thesis submitted to School of Graduate Studies of Addis Ababa University in partial fulfillment of the requirements of the Degree of Master of Science in Industrial Engineering

**ADDIS ABABA UNIVERSITY**  
**ADDIS ABABA INSTITUTE OF TECHNOLOGY**  
**SCHOOL OF MECHANICAL AND INDUSTRIAL ENGINEERING**



A frame work to enhance the technology transfer for high rise building construction: A case study of CBE HQ project

---

By: Melat Solomon

Addis Ababa, Ethiopia

October 2018

A Thesis submitted to School of Graduate Studies of Addis Ababa University in partial fulfillment of the requirements of the Degree of Master of Science in Industrial Engineering

ADDIS ABABA UNIVERSITY  
ADDIS ABABA INSTITUTE OF TECHNOLOGY  
SCHOOL OF MECHANICAL AND INDUSTRIAL ENGINEERING

“A frame work to enhance the technology transfer for high rise building construction: A case study of CBE HQ project”

**By**

**Melat Solomon**

Approved by Board of Examiners:

Dr. Ermyas Tesfaye

**Advisor**

**Signature**

**Date**

Dr. Gulelat Gatew

**Internal Examiner**

**Signature**

**Date**

Dr. Netsanet Jote

**External Examiner**

**Signature**

**Date**

**Chairman of School Graduate**

**Signature**

**Date**

**Committee (SGC)**

## DECLARATION

I hereby declare that the work which is being presented in this thesis entitle “A frame work to enhance the technology transfer for high rise building construction: A case study of CBE” is original work of my own, has not been presented for a degree of any other university and all the resources of materials used for the thesis have been duly acknowledged.

---

Melat Solomon

---

Date

(Candidate)

**This is to certify that the above declaration made by the candidate is correct to the best of my knowledge.**

---

Dr. Ermyas Tesfaye

---

Date

(Thesis Advisor)

# TABLE OF CONTENTS

LIST OF FIGURES .....	VI
LIST OF TABLES.....	VII
LIST OF ABBREVIATIONS.....	VIII
ACKNOWLEDGEMENT .....	IX
ABSTRACT .....	X
<b>CHAPTER ONE .....</b>	<b>1</b>
<b>BACKGROUND OF THE STUDY.....</b>	<b>1</b>
1.1.    INTRODUCTION.....	1
1.2.    PROBLEM STATEMENT .....	1
1.3.    OBJECTIVE .....	4
1.3.1.    General Objective.....	4
1.3.2.    Specific Objective .....	5
1.4.    RESEARCH METHODOLOGY .....	5
1.5.    SCOPE OF THE STUDY.....	5
1.6.    SIGNIFICANCE OF THE STUDY .....	6
1.7.    ORGANIZATION OF THE STUDY .....	6
<b>CHAPTER TWO.....</b>	<b>7</b>
<b>LITERATURE REVIEW .....</b>	<b>7</b>
2.1.    TECHNOLOGY TRANSFER IN CONSTRUCTION INDUSTRY .....	7
2.2.    CHANNELS OF TECHNOLOGY TRANSFER.....	9
2.3.    BARRIERS OF TECHNOLOGY TRANSFER .....	11
2.4.    DETERMINANTS OF TECHNOLOGY TRANSFER.....	12
2.5.    REVIEW OF MCDM METHODS.....	18
<b>CHAPTER THREE.....</b>	<b>25</b>
<b>RESEARCH DESIGN AND METHODOLOGY .....</b>	<b>25</b>
3.1.    INTRODUCTION .....	25
3.2.    METHODOLOGY .....	25
3.3.    POPULATION .....	27
3.4.    SAMPLING APPROACH.....	27
3.5.    DATA COLLECTION .....	27
3.5.1.    Questionnaire Design .....	28
3.6.    DATA PROCESSING AND ANALYSIS.....	29
3.6.1.    Multi Criteria-Based Decision Making (MCDM) and Fuzzy Set.....	30
3.6.2.    Linguistic variables .....	31
3.6.3.    FUZZY TOPSIS.....	32
<b>CHAPTER FOUR .....</b>	<b>36</b>
<b>DATA PRESENTATION AND ANALYSIS.....</b>	<b>36</b>
4.1.    DATA PRESENTATION .....	36

4.1.1.	Contents of the Questionnaire .....	36
4.1.2.	Target Population .....	36
4.2.	DATA ANALYSIS AND DISCUSSION .....	45
4.2.1.	Development of fuzzy set.....	45
<b>CHAPTER FIVE .....</b>		<b>56</b>
<b>RESULT AND DISCUSSIONS .....</b>		<b>56</b>
5.1.	INTRODUCTION .....	56
5.1.1.	Aggregated Fuzzy Decision Matrix.....	56
5.1.2.	Normalized Aggregate Fuzzy Decision Matrix .....	57
5.1.3.	Weighted Normalized Aggregate Fuzzy Decision Matrix.....	59
5.1.4.	Fuzzy Positive Ideal Solution (FPIS) & Fuzzy Negative Ideal Solution (FNIS).....	60
5.1.5.	Distance of each alternative from FPIS & (FNIS).....	61
5.1.6.	Closeness coefficient .....	65
5.2.	DISCUSSION .....	66
5.2.1.	Transferee perspective for the barrier of technology transfer.....	71
5.2.2.	Transferor perspective of the local workers on site.....	71
5.2.3.	Transferee perspective on the determinants/factors for the success of technology transfer .....	71
<b>CHAPTER SIX .....</b>		<b>81</b>
<b>FRAMEWORK OF DETERMINANTS OF TT TO BE IMPLEMENTED IN PROJECT LIFE CYCLE .....</b>		<b>81</b>
<b>CHAPTER 7.....</b>		<b>92</b>
<b>CONCLUSION AND RECOMMENDATION .....</b>		<b>92</b>
7.1.	CONCLUSION .....	92
7.2.	RECOMMENDATION .....	93
<b>REFERENCE .....</b>		<b>94</b>
<b>ANNEX.....</b>		<b>98</b>
ANNEX 1: QUESTIONNAIRE.....		99

## List of Figures

Figure 1: General Conceptual model for technology transfer .....	9
Figure 2: Published articles on MCDM methods .....	22
Figure 3: Transferee opinion (Rate) about the transferor .....	39
Figure 4: Transferee opinion (Rate) about the transferor .....	40
Figure 5: Transferor opinion (Rate) about the transferee (From the Experts).....	41
Figure 6: Transferor opinion (Rate) about the transferee (From Technicians View).....	42
Figure 7: Life cycle of a construction project.....	81
Figure 8: Project Initiation phase.....	82
Figure 9: Project Planning phase .....	84
Figure 10: Project Implementation phase .....	85
Figure 11: Frame work for implementing technology transfer in project life cycle.....	87

## List of Tables

Table 1: Summary of the selected studies on Technology transfer and its determinants .....	16
Table 2: Reviewed Studies on Multi Criteria Decision Making methods .....	18
Table 3: Respondents Criteria.....	27
Table 4: Description of Linguistic variables.....	30
Table 5: Fuzzy Ratings for Linguistic Variables .....	31
Table 6: Company Profile of Respondents of the client representative (AAiT).....	37
Table 7: Company Profile of Respondents of the Contractors (CSCEC).....	37
Table 8: Questionnaire Return Rate.....	38
Table 9: Number of decision makers (related with their criteria) rating the alternatives (Determinants/Factors) .....	43
Table 10: Fuzzy ratings for linguistic variables.....	45
Table 11: Fuzzy rating for Determinant/Factor 1 .....	46
Table 12: Aggregated fuzzy rating for Determinant/Factor 1 relative to criteria 1,2 & 3 .....	48
Table 13: Normalized fuzzy decision matrix for Determinant/Factor 1 with respect to each criterion .....	49
Table 14: FPIS & FNIS.....	52
Table 15: The distance of Alternative1 from the FNIS & FPIS .....	54
Table 16: Closeness coefficient .....	55
Table 17: Computed aggregated fuzzy decision matrix .....	56
Table 18: Normalized Aggregate Fuzzy Decision Matrix .....	57
Table 19: Weighted Normalized Aggregate Fuzzy Decision Matrix .....	59
Table 20: Fuzzy Positive Ideal Solution (FPIS) & Fuzzy Negative Ideal Solution (FNIS) .....	60
Table 21: Distance of each alternative from FPIS & (FNIS).....	63
Table 22: closeness coefficient & Ranked result .....	65
Table 23 Importance of factors/determinants of technology transfer.....	67
Table 24: Identified Problems in Technology transfer between the transferee (CSCEC) and transferor (local employees) .....	73
Table 25: The means of verification, variable indicators and responsible body for technology transfer in project life cycle .....	88

## **List of Abbreviations**

TT - Technology transfer

FDI - Foreign Direct Investment

MNC - Multinational company

MCDM - Multi criteria Decision maker

CBE HQ – Commercial Bank of Ethiopia Head Quarter

AAiT - Addis Ababa Institute of Technology

CSCEC -China State Construction Engineering Cooperation

TOPSIS – The Technique for Order preference by similarity to ideal solution

AHP – Analytic Hierarchy Process

SAW – Simple Additive Weighting

## **ACKNOWLEDGEMENT**

I would like to express my special appreciation and thanks to my advisor Dr. Ermias Tesfaye for his advice and support throughout the research.

Many thanks also goes to Ato Fitsum Getachew (PHD candidate), AAiT instructor from school of industrial engineering for his assistance. All senior engineers in the AAiT supervision team on CBE HQ project, Ato Samson Walelegn , Ato Alemayehu Ayalew, Ato Yisshak Tadesse, w/rt Hana Mekuria, Ato Fikremariam Tamrat for constant help, and sharing their work and assisting me throughout the research. Dr. Germaye from School of Civil engineering for his advice in project management. CBE HQ for supporting me throughout the research, CSCEC workers for sharing their information on their experience of the project and Ato Nathnael H/Mariam for his constant support.

Most of all, next to God, I would like to pass my gratitude to my family and all my friends who gave me their care and support.

## ABSTRACT

The high-rise building construction in Ethiopia has been developed through time which in other words increases the country's construction industry development. However, the construction of high-rise building has been handled by foreign international contractors due to low capacity of Ethiopia's construction industry to such buildings. This is due to lack of materials, machineries, equipment, tools, design, management knowledge, new technologies and so on. Even though the high-rise buildings are being constructed by the foreign international contractors for the use of the country in many ways, the local workers must participate and learn new technologies and knowledges from them by using the advantages of working together. This thesis explores the factors that affects the technology transfer in construction project, to be specific in a high-rise building construction industry, prioritize the determinants of technology transfer and develop a frame work for the success of Technology transfer and adaptation. In order to achieve the mentioned purpose, written journals and literatures has been reviewed and with regard to the factors and determinants that drives the success of technology transfer in construction industry in general. For this case study, Commercial Bank of Ethiopia head Quarter (CBE HQ) project is taken. Eighteen technology transfer determinants are identified through detail literature review as well as by studying on the case study project on site. Once important determinants are factored out, questionnaire survey distributed to understand and know the opinion of the experts, engineers and the laborers and rank the determinants as per their importance through the worker's opinion in the project. The analysis is carried out using fuzzy -TOPSIS method to address both objective and subjective opinions in the ranking of the determinants and factors for the success of technology transfer. Since the opinion of workers differs due to their work experience, the respondents are also weighted. The weighting of the criteria is carried out using Fuzzy AHP method.

At the end of this study, a frame work is developed and proposed to implement the determined factors on a project life cycle. Furthermore, means of verification, variable indicators and responsible party for implementing the determined important factors on the project life cycle id discussed.

**Key word: Key word:** Technology Transfer, Building Construction project, determinants/factors of Technology transfer, Fuzzy set, Fuzzy TOPSIS

## CHAPTER ONE

### BACKGROUND OF THE STUDY

#### 1.1 Introduction

Construction industry is one of the vast sectors of the economy identified by Ethiopia government to encourage the country's economic development. (EEA.2018) However the domestic construction industry in Ethiopia is still practicing with insufficient capital support, limited skills of managerial, technical, consulting, labor, equipment and safety practice. In many developing countries they manage to control this problem by taking a chance with technology transfer through different means, to mention some of them: training components in joint venture agreements between foreign and local partners, trade in goods and services, foreign direct investment and so on. This has been practiced in so many developing countries in order to achieve economic development. Experts in this field address the need of copying, adopting as well as creating technology to be the most essential aspect in different areas (Bell 1984; Putranto. 2003; Wie, 2003) This is a way of transferring new technology from those who have it to those who needs it. This paper is more concerned about finding out the key technologies to adopt in construction areas and modeling a mechanism to adopt the technology and knowledge to be transferred so as it is useful to practice it on the coming new projects. Just like different industries, new technologies are introduced to construction areas constantly. Some of the most important technologies that should be adopted and practiced includes: project management system, Design review and designing, Building at speed, Smart tools, Constant inspection, Safety and quality control. (Gebrehiwet and Luo 2017), (Saurin 2016), (Poh, Ubeynarayana et al. 2018)

The contractors are the major actors in any construction project since they are the ones who take up all the responsibility to undertake the whole construction activities and related tasks which includes procurement of materials, deployment of all the necessary machinery, equipment and human resource, managing the financial resources and converting all resources into the intended project outputs. In the case of constructing a high-rise building in Ethiopia, it is known that we face lots of problems, such as being characterized by poor performance leading which leads to failure, new technologies not applied on the construction, new techniques, skills, machineries, equipment not being available on the construction project, the manpower working on the project

not having a skill and so on. Even though the opportunity for building construction in Ethiopia is growing, the complexity is growing as well. In order to solve these problems, many developed countries practice the involvement of international foreign contractors in their country through different means, such as foreign direct investment (FDI), joint ventures (JVs), licensing, franchising, turnkey contracts and international subcontracting. As mentioned, there are different means of constructing high-rise buildings in the developed countries, the big question is how the developed countries use this opportunity towards their advantage to learn, transfer & adopt the technologies used by the foreign contractors and practice them on the upcoming new projects. as much as building high rise buildings in Ethiopia is growing in times, the involvement of local workers, suppliers & contractors is not practiced much. As much as the involvement of foreign contractors to build this kind of construction in our country is important, the involvement of the local firms and workers is very important not to depend on them all the time. In addition to that, through learning and practicing, the local contractors and the workers will develop their capacity, as well as the country's capacity of construction through time. So how can we learn new technologies? How can we adopt and the practice it on the project until it gets to the point where the local contractor can handle big construction projects using new techniques, machineries & equipment? It must be identified what new technologies must be transferred, practiced & adopted, the means for the process of technology transfer and then at last how to apply it on new projects for the success of the technology transfer to occur.

## **1.2 Problem Statement**

As important it is to build high rise buildings in every country, it is also important to be aware of what is to be done and how it is being done. To this day technology plays a big role in economic growth, to be independent, to have power as well as to compete with developed countries. Hence, the main problem in our country is not having difficulty in constructing a high rise building, since we can outsource the construction to international contractors who has the capacity to build such kind of building. But as the host country, Ethiopia does not get the privilege to learn and experience new technologies that are being used to build Highrise buildings, from the foreign/ international companies. Therefore, what are the outcomes of the foreign contractors working on our country. We can say new big projects, buildings, industries are being built. So, by letting the foreign contractors handling the projects, what else can we be able to get out of it? This is important

because the time where the local contractors handling such kind of big projects together with the foreign contractors and also on their own must come in the near future.

Technology transfer is one of the most important aspect that can be adopted by training, practicing and introducing ourselves to new knowledges, techniques and skills. The advantage of the foreign contractors working in developed countries is that there is different means to work with them and develop our capacity by learning. Here, as being a developing country, we must be smart on using the opportunity on our advantage. Instead of letting the international well-developed countries handling the construction project, there has to be means where integration of local workers with the foreigners happens. Through getting trainings and practicing on the work with the foreign contractors, one can develop their capacity. Not only integrating workers only, but also integrating the local contractors, consultants & institutes with the foreign contractor will enlarge the knowledge and technology transfer. Even though there are opportunities the local workers or the sub-contractors to get involved in this kind of joint works, the technologies has not been transferred properly as it is suppose to. To begin with, we must be smart on how to take the advantage to work with the foreign international contractors to ourselves starting from the beginning until the end. Which means, it is very important to understand the main means of technology transfer in a given project from the foreigners to the local workers and how it can be adopted. Then, it must be checked how deep the technology is being transferred as such the host country are comfortable and well aware of the technology in order to practice in their country.

Even though there are different means of technology transfer in construction industry in Ethiopia, such as, Foreign direct investment (FDI) is also another means of technology transfer where Multinational enterprises (MNEs) transfer technological information to their subsidiaries, some of which may leak into the host country(Osabutey and Croucher 2018), the technologies are not well adopted and practiced by the local contractor. This will make Ethiopia to be dependent on the foreign contractors or trade. Hence, construction sectors must not only develop or create a means for technology transfer but the main factors and determinants for the technology transfer must be identified. Therefore, instead of just letting foreign companies or developed countries handle most of our Highrise construction projects and big projects, we must identify the main means to learn and work with the foreign contractors, for the success of technology transfer. Once the means to work with the foreign contractors is established, it must be identified how these new

technologies/knowledges can be successfully transferred and can be adopted. This way, it is very simple to have a trend of learning, adopting and then practicing the new technologies to our upcoming construction projects by constructing a strategy. It is known that Ethiopian construction industry is not well developed by its own and do not have the luxury to sit back and let the foreign companies handle the construction projects. We must be involved throughout the whole process of the project life time and learn how to transfer the new technologies. In this study, the given case study is Commercial Bank of Ethiopia New Head quarter (CBEHQ) project. This project is the biggest high-rise project in Ethiopia so far with 4 basements and G + 48 floors with. This project is estimated to cost over 6 billion Ethiopian birr. The high-rise building project is number one in Ethiopia and ranked on third level throughout Africa. This project is the biggest asset for Ethiopia, since it is government owned project.

Hence this study attempts to answer the following questions.

- What are the barriers for the success of technology transfer in construction industry projects and in a given case study CBEHQ project?
- What are the factors (determinants) and the drivers for effective technology transfer and adoption in the construction projects in general?
- What kind of multi-criteria decision-making approaches, must be developed for identifying the determinants of technology transfer and compare their importance in case of Commercial Bank of Ethiopia New Head Quarter project?
- How to construct a frame work relating the determined factors of technology transfer with project life cycle?

## **1.3 Objective**

### **1.3.1 General Objective**

The general objective of the study is to determine the means for the success of technology transfer and propose a frame work relating the factors to implement it on a project life cycle for the purpose of future work in a high-rise building construction project.

### **1.3.2 Specific Objective**

The specific objectives of the study are:

- To determine the barriers of technology and knowledge transfer in construction projects and relate it with the chosen case study, (CBE HQ) Project.
- To identify the major determinants for technologies and knowledges to be transferred in construction industry project specifically in Commercial Bank of Ethiopia Head Quarter (CBE HQ) Project.
- Developing multi-criteria decision-making approaches, for identifying the determinants of technology transfer in in case of Commercial Bank of Ethiopia New Head Quarter project.
- To construct a fame work relating the determined and ranked factors of technology transfer with project life cycle.

### **1.4 Research Methodology**

The objectives set in this paper is addressed through literature review, data collection and data analysis supported by logical discussion.

### **1.5 Scope of the Study**

The study focuses on identifying the main factors/determinants of technology transfer in construction projects mainly through literatures and analyzing this and prioritizing them accordingly then developing a frame work based on the rated or ranked determinants relating it with the project life cycle. This research was done on projects of Commercial Bank of Ethiopia Head Quarter (CBEHQ), from client's representative and foreign contractors (China State Construction Engineering Cooperation) through survey questionnaire and interview. The study is only from the perspective of the CBEHQ project and did not consider other construction industry. The study is also limited to the client representative (AAiT) of CBEHQ project and experts, local engineers and laborers from the foreign contractor (CSCEC) who meets the selection criteria.

## **1.6 Significance of the Study**

The main significance of the study is to determine the main factors for the success of technology transfer and establish a frame work for capacity building of local contractors for upcoming new projects. After identifying the factors, to develop a framework relating with the project life cycle from the opinion and answers that has been given from the respondents.

## **1.7 Organization of the Study**

The study is organized in seven major chapters. The first chapter included the Background of the study. The second chapter is the Literature Review of the study which discuss about the concept of modeling a mechanism for technology transfer adaptation in construction industry. The research design and methodology are discussed on chapter three. The modeling methodology is discussed on chapter four. On chapter Five the result and discussions of the data, based on the presented theory. The sixth chapter include the proposed frame work and the seventh chapter includes conclusions, and the last parts includes recommendations references used and appendixes.

## **Chapter two**

### **Literature Review**

Construction industry is one of the most important sectors for the development of economy which gives contribution to gross domestic products (GDP), capital formation, and employment. The construction industry in most developed countries has failed to give the expected outcome for the basis for socio economic development as well as the living conditions of the community. (Ofori G. , 2006) Construction project is crucial due to creating job opportunities for the people, making the country an attractive place for foreign direct investment while improving the quality of the work, and making one's country company to compete with foreign firms entering the markets in the area of globalization. The study of construction industry in developing countries have been studied since 1950's (Ofori G. , 2001). Studies assure that the need of construction in developing countries must be improved as it is the most important mechanism for the development of national socio-economic development. Construction is a large sector of the economy, contributing a significant proportion of the national economy during each period as (Hillebrandt, 2001) explained it. It also takes place in all parts of the country and can be used to develop entrepreneurship, and transfer technologies to all the citizens of the country.

#### **2.1. Technology Transfer in construction Industry**

Technology plays a big role for the development of construction industry. Construction technology is the combined element of construction methods, construction resources, work tasks and project influences that define the manner of performing a construction operation. (V Kumar), also tried to discuss about technology in his paper which includes two primary components: (1) a physical component, which includes products, equipment, techniques, and processes, and (2) an information component, which includes know-how about management, marketing, production, quality control, reliability, skilled labor, and functional areas. Even though new technologies are very helpful for the development of construction it is known that it is not well practiced in developing countries, due to so many reasons. Some of the reasons and main issues addressed are: construction industry development; Local construction companies lacking the technical and managerial capability to undertake most of the foreign-funded projects, globalization; culture (the impact of the nation's culture on construction activity, the culture of the construction project, the

culture of the construction firm, the culture of the construction site ); and the environment (The environmental problems of the developing countries exist together with a lack of the managerial experience, financial resources, and legal and administrative systems necessary to deal with the issue through public and formal education, formulation and enforcement of “command and control” measures (legislation and regulations), as well as the devising and implementation of “economic instruments” (incentives – grants, subsidies – and taxes) (Ofori G. , 2006). (Hagopian, 1984) proposed that for the developing countries, the involvement of foreign contractors is a key requirement for development of the local construction industry. This benefits the local contractors of the developing countries to learn and adopt new technologies from the foreign contractors which means the need for technology transfer from the transferor (the foreign contractor) to transferee (the host). Technology transfer contains a two-way process, which can succeed only when both the donor and the recipient work together to decide what needs to be transferred and implemented (Sridharan, 1994). Technology can be defined as a transformer, a tool, as knowledge and as a specialized knowledge (Panda & Ramanathan, 1995). It involves the transfer of knowledge, best practice, know-how, implication process and expert. Technology transfer is the drive of technology from one site to another, namely from a University to an organization, from one organization to another, and from one country to another (Bolatan, 2016).

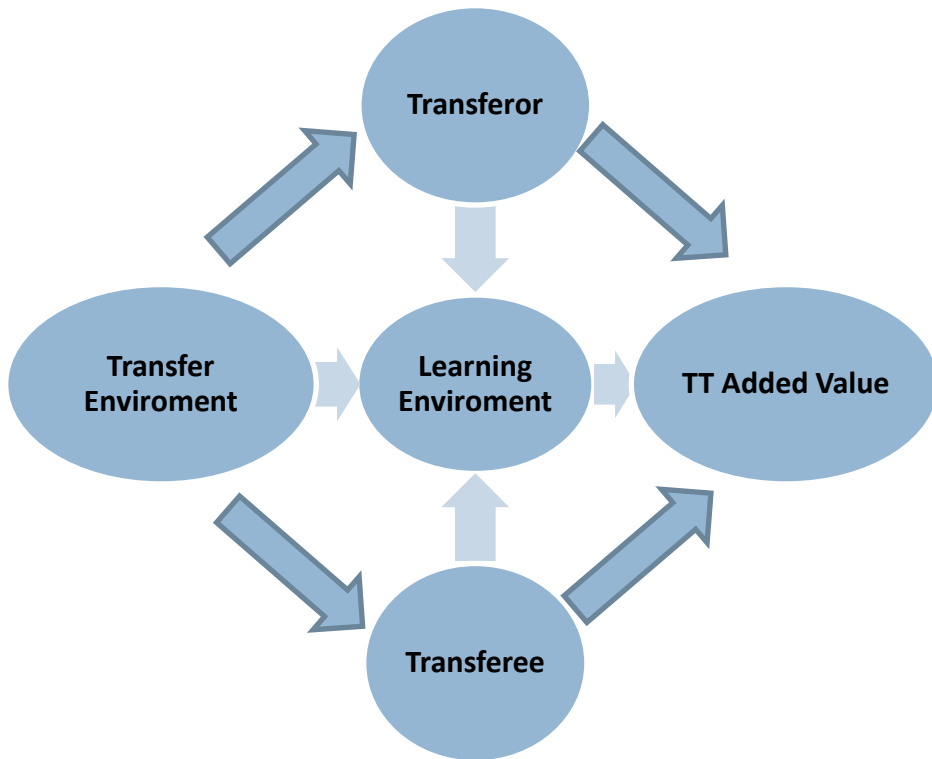


Figure 1: General Conceptual model for technology transfer

## 2.2. Channels of Technology Transfer

There are different channels for the success of the mentioned new technologies to be transferred. (Harv, 1991) tried to discuss and sort out different techniques that can be used for the means of technology transfer. These techniques include forms in which technology may be transferred and methods of transferring technologies. The forms in which technologies can be transferred include machinery or other intermediate goods which is suitable for manufacturing process, through individual experts which is usually relative to employed ones and is usually suitable only for small and medium sized projects where technology is simple, and the last form includes through technology know-how, patented or unpatented. The methods of transferring include direct foreign investment, Turn-key packages, technology license agreements & management contracts. In his study he tried to see the good and bad side of different mechanisms of the methodologies mentioned above. Direct foreign investment is usually in favor of the foreign investors when it is fully controlled by them. This might be difficult for the host country to get the new technologies that must be adopted from the foreign investors. In turnkey packages, the developed countries sold the entire technology package, which left the developing countries no choice to select their needs

from the package. The foreign investors provide the developed countries on-going technical changes as they are developed during the life of the agreement. In his study, from all the methodologies used by the developing countries to transfer new technologies from those developed countries, he found out that licensing method is the most adaptable methodology which allows the host countries to practice it while the project is in ongoing process.

Technology transfer occurs because of the existence transferor and transferee. It normally refers to formal and direct arrangements between a transferee and a transferor or non-commercial arrangements between donor and recipient. This form of transfer in particular, may well be a two-way process between transferor and transferee. According to (D Bennett, 2004) technology transfer can be described as tools, machine, electrical or mechanical component, a chemical process, software code, a patent and a technique transfer. The mentioned technologies to be transferred and adopted can be benefited to developing countries in the form of generating greater revenues. Furthermore, (D Bennett, 2004) tried to describe the means for technology to be transferred. These are: between persons, between organizations, between regions and countries. Transferor and transferee play a major role in which, the transferor willing to transfer the technology and the transferee willing to learn the technology, hence encourages the technology transfer process.

(R Takim, 2009) tried to study the major channels of international technology transfer (ITT) projects in Malaysia and how these channels and technology capabilities are flow within the Malaysian construction industry. Once (R Takim, 2009) identified the channels, a conceptual framework proposed for a successful ITT and development of technological capabilities for the Malaysian construction industry. In the study several channels of the international technology transfer which opened for Malaysia were able to be identified. Direct investment (domestic and foreign) and privatization are included in these channels. Through privatization channels, foreign technology is transferred by means of build-operate-transfer (BOT) and Private Finance Initiative (PFI) procurement systems. After studying and finding out that Malaysia has a more focused strategy to market construction services through Government-to-Government arrangements abroad, (R Takim, 2009) have proposed conceptual framework for a successful international technology transfer (ITT) and development of technological capabilities in Malaysian Construction Industry. This has been developed based on a preliminary literature review

undertaken on technology transfer processes and consists five major components which includes the types of technology (knowledge, skills and tools), the channels, the variety of stakeholders, barriers and the benefits of ITT projects.

(Odedra, 1991) describes technology transfer channels through the application of licensing which is to be applied singly or in combination with other instruments such as foreign investment, import of machinery or/and technicians as an instrument for technology transfer. As the study explains it, Direct Foreign Investment (DFI) in branches or subsidiaries of multinational corporations is also a way of obtaining technology from abroad. This can ensure a rapid transfer of technological information and means.

(Mselle, 2014) tried to present findings of a study related to enabling channels for technology transfer in the Tanzania construction industry. The study was based on semi-structured interview used to collect data from stakeholders who were contractors, consultancies, regulatory bodies and a research center. After he studied the level of technology transfer in construction industry in Tanzania and discovered that it was very poor and not well practiced, he tried to identify the channels which can be used as a technology transfer and to adopt the technology. These channels which were helpful for the technology to be transferred includes establishment of formal arrangement to transfer technology, improving partnership between construction industry and research centers, capacity building of local firms, building a research culture among professionals and establishment of a technology transfer and research fund for construction industry. (Mselle, 2014) identified different channels or modes of technology transfer which includes; direct, indirect, commercial and non-commercial channels. The direct channels could be regarded as managerial and institutional comprising of operating international cooperation, licensing agreements, hiring expert and contractor, and training of technical staff to abroad. The indirect channels are the purchase machinery, exchange information at international meetings and attend exhibitions and trade fairs.

### **2.3 Barriers of Technology Transfer**

Even though there are different channels for the implementation of technology transfer, there are also barriers for the technologies not to be transferred. (CB Tatum, 1986) identified the major barriers which includes lack of focus on the learning mechanism, insufficient resource allocation

for training, enlarged institutional gap(in terms of the structure of the organization, financial status, equipment ownership, managerial and technical level and communication system) between the transferor and the transferee, all the managerial functions were looked after by the foreign agent which led to a problem when the ownership of the firm was transferred to the local counterpart and the staff confronted with difficulties in adapting to the new challenges and the last barrier was the organizational attitudes towards new technologies. Li-Hua (2004) described in his paper that potential barriers must be considered as barriers to the success of technology transfer. He also estimated that the barriers of knowledge transfer to be cultural differences, language barriers, social values, and different objectives. (BL Kedia, 1988) identified that among others, culture difference has become the major barrier in international technology transfer which exists between the technology provider and the technology receiver. This is pointed out that for the technology transfer to function properly, the organizations involved in the process should endeavor to build a culture of mutual trust through effective communication between transferor and transferee. Working in unfamiliar markets is often burdened with difficulties due to culture differences. (Harv, 1991)From the identified technology transfer barriers some of them includes: Organizational culture, Lack of time, Capacities of individuals, Attitudes of individuals, Lack of clear policy, National /ethnic culture differences, Lack of clear agreements, Lack of clear procedures, Lack of funding provisions, and Language, attitudes of the individuals and lack of clear policy.

## **2.4 Determinants of technology transfer**

Once the channels for technology transfer is understood, then what are the factors enabling the technology transfer? (Mselle, 2014) identified factors such as improvement of infrastructures for technology transfer, establishment of fund for technology transfer and formal arrangement for TT need government policies to be very important for the need of Technology Transfer (TT). For formal arrangement of TT and capacity building, local construction firms need some modification in Public procurement Act (PPA) so that mandatory joint venture and sub-contracting part of the work to local firms are also included. He described hat the capacity building needs joint efforts between firms and government to make sure that Public procurement Act creates a preferential arrangement to local firms so as to improve their capacity which he also identified as another enabling factor for TT. At last he tried to suggest that the government are the ones to take role in TT for the construction industry by addressing factors which require legal or policy framework.

(Rodney A. Stewart, 2007) (T Waroonkun, 2008) discussed on different technology transfer enablers. This include, transfer environment: where technology transfer in construction projects are mostly produced by turnkey systems, direct licensing agreements, management contracting or joint ventures. According to his paper, host government's policies, regulations and enforcement practices can impact greatly on the effectiveness of technology transfer initiatives, especially with their international political system and domestic political structure. Those government policies should provide initiatives to transferor to transfer technology proactively to local competitors. Learning environment: where culture and the distance between the technology transferor and transferee is a major concern of technology transfer process and explains that in order to have an effective technology transfer process, the parties involved in the process must build a culture of mutual trust through effective communication.

(Ganesan, 2002) tried to explain the need of accepting the transferor (foreigner) and transferee (host) commitments for the success of technology transfer. To achieve a successful technology transfer, the transferor should transfer the appropriate technology and the transferee should have every intension to adopt it. Furthermore, the degree of international experience of both parties and the nature of experience can impact significantly on the technology transfer process. In addition to commitment, he also discussed on the capacity to transfer and adopt technology which depends on each individual existing knowledge base and the gap between this knowledge level and the level required utilizing the transferred technology. Finally, he concluded that effective transfer of technology within the confines of single projects cannot be a major vehicle for TT to domestic industries as a whole; nevertheless, joint ventures (JVs) and Subcontracting agreements SCAs involving foreign parties are beneficial in a number of areas.

(Shrestha, 2002) explained the need of the transferor and transferees' culture for working in partnership to get on the TT process. Capacity of the local construction industry to assimilate, adopt, modify, and generate technology is critical to an effective transfer of technology. This capacity building cannot be done only by importing technologies from foreign countries but also through advanced man power and management training, domestic production of materials, tools and equipment, and individual innovation focused on construction industry.

(Antwi-Afari, 2006) has shown the need for opportunities for obtaining knowledge about designs and construction planning, and education and training programs within construction joint ventures in order to train local firms on newly established construction technologies and construction knowledge. If locals get to participate at early stage of design & construction, it is easy to absorb, adopt and implement appropriate construction technology. (Antwi-Afari, 2006)also tried to explain the need of open and positive attitudes among the parties will encourage technology transfer from foreign firms to local construction firms.

(DG Owusu-Manu, 2017) tried to identify the enablers for technology transfer process, which includes transferor and transferee characteristics, knowledge advancement, the transfer environment, government influence, the learning environment, project performance, communication, and relationship building and absorptive capability were identified first. The study provided useful guidance to local and international funding agencies, governments of developing or newly industrialized countries, and construction firms that seek to effectively evaluate the success (or otherwise) of the TT process. They have also advised on their paper that future research should seek to validate the research findings presented, and to expand the work to include other developing countries. Connectedness and networking dynamics, Prior experience in international construction project and trust and common objective were found to be important determinants for technology transfer (Carina Araujo, 2004). (ARVANITIS, 2005)The study describes the main factors of technology transfer to be absorptive capacity of the employed local workers & provision of formal training. (GIBSON, 1991) describes in his paper that importance of universities in accessing knowledge transfer, importance of government in accessing knowledge, importance of government in building innovation, importance of government in commercializing innovation as factors for the success of technology transfer. (Gopalakrishnan, 2004)identified in their study that trust (Willing to share ideas, feelings and goals, fairness in sharing different skills, Sharing of a set of principles that the company finds acceptable) to be important factor for technology transfer to exist. (NM Reddy, 1990)Identified the main factors for the success of technology transfer in his study. The identified factors include: need of absorptive capacity of the transferee, local employee to take training from the transferor, need of smooth relationship between the transferor and transferee & hiring experienced transferee. (Lin, 2002)The key success factors for technology transfer includes: technological readiness of the transferee, the design being consistent with the

transferee's needs and capabilities, the use of appropriate technology, the transferee country must having an appropriate enabling and regulatory environment relative to the technology being transferred, establishment of long-term mutually beneficial partnership arrangements, the identification of a local "change" agent as a champion for the technology, the society having the necessary infrastructure elements to support the diffusion of the technology.

**Table 1: Summary of the selected studies on Technology transfer and its determinants**

No.	Author	Title	Method of identification and analysis	Goal of the study
1	(Mselle, 2014)	An Evaluation of Enabling Factors for Technology Transfer in Tanzania Construction Industry	<ul style="list-style-type: none"> <li>• Literature Review</li> <li>• A semi-structured interview</li> <li>• Interview questions were designed</li> </ul>	To identify the level of technology in the construction industry and enabling factors for technology transfer in the construction industry.
2	(Rodney A. Stewart, 2007)	Benchmarking construction technology transfer in Thailand	<ul style="list-style-type: none"> <li>• Literature Review</li> <li>• Questionnaire survey</li> </ul>	In an attempt to better diagnose the health of international construction technology transfer (TT) projects and improve rates of TT
3	(Ganesan, 2002)	Technology transfer subcontracting in developing countries through	<ul style="list-style-type: none"> <li>• Literature Review</li> <li>• Questionnaire survey</li> </ul>	The study discussed on the problems and prospects of internal transfer of technology within the domestic construction sector in order to boost domestic capacity.
4	(Antwi-Afari, 2006)	Targeting 'technology exchange' for faster organizational and industry development	<ul style="list-style-type: none"> <li>• Literature Review</li> <li>•</li> </ul>	To critically review the existing literature to construct the prospective enabling and outcome factors of TT process

5	(NM Reddy, 1990)	International technology transfer: A review	<ul style="list-style-type: none"> <li>Literature Review</li> </ul>	To review the international technology transfer literature & proposed an organized framework in line with key elements of international technology transfer
6	(ARVANITIS, 2005)	Determinants of Knowledge and Technology Transfer Activities between Firms and Science Institutions in Switzerland	Questionnaire survey	To get involved in knowledge and technology transfer (KTT) activities in order to gain new implicit and organized scientific knowledge in research fields.
7	(DG Owusu-Manu, 2017)	Modelling a conceptual framework of technology transfer process in construction projects: an empirical approach	<ul style="list-style-type: none"> <li>Questionnaire survey</li> <li>Literature Review</li> <li></li> </ul>	To present a conceptual framework of the TT process as a tool for measuring construction performance
8	GIBSON, D. V., Smilor, R. W. (1991)	Key variables in technology transfer: a field-study based empirical analysis	<ul style="list-style-type: none"> <li>Interview</li> <li>Archival</li> <li>Survey data collection</li> </ul>	To present new organizational form which highlights barriers and clarifies solutions to efficient and timely technology transfer

## 2.5 Review of MCDM Methods

For this thesis, the factors/determinants for technology transfer is identified through literature review to investigate the existing factors of TT from the international and within the African context, which is going to be used as a base line to design a questionnaire and interview among project owners & contractors to obtain actual data.

The literature shows besides the main identifying factors for Technology transfer, different tools that are employed for measuring the identified factors/determinants for technology as per their importance. Since the tools to be used must focus on technique for multi criteria decision maker which is related to thesis, more focus is on MCDM tools. Different studies showed the effectiveness of applying Multi Criteria Decision Maker (MCDM) methods in the areas of sustainable and renewable energy applications (Mardani, Jusoh, Zavadskas, Cavallaro, & Khalifah, 2015). The development of MCDM methods has been widely described in the literature throughout the years. (Vincke, 1992) Described that multiple criteria decision making (MCDM) is the most of the time characterized by a set of multiple criteria method. From 1950s, there had been a large number of advanced MCDM methods developed and they differ from each other in the required quality and quantity of, the methodology used, easiness of their used, verifying the mathematical properties and the given information. Fuzzy MCDM has basically been developed with the help of fuzzy set theory and number of different inventions have been made possible (Zavadskas, 2011).

**Table 2: Reviewed Studies on Multi Criteria Decision Making methods**

NO.	MCDM Analysis Method in Different Researches	Reference
1	New developments and maintenances of the existing infrastructures under limited government budget and time	Yan (2011)
2	An improved voting AHP-data envelopment analysis methodology for supplier's selection	Hadi-Vencheh and Niazi-Motlagh (2011)

3	AHP weights used to fill missing gaps in Markov decision models.	Steuten (2010)
4	Improving the quality for passenger transportation	Sivilevicius and Maskeliunaite (2010)
5	Fuzzy AHP (FAHP) and the three MCDM analytical tools of SAW, TOPSIS, and VIKOR respectively adopted to rank the banking performance and improve the gaps with three banks.	Wu (2009)
6	Fuzzy AHP method applied used for the approach to select a suitable enterprise resource planning system for textile industry.	Ananda and Herath (2008)
7	Modified fuzzy TOPSIS	Han and Liu (2011)
8	Fuzzy TOPSIS methodology used for the selection of the most desirable support structure of an offshore wind turbine, among three design options, under the consideration of a combination of multiple qualitative and quantitative criteria	Lozano-Minguez (2009)
9	Introduced TOPSIS which takes into consideration the stochasticity of inputs, which is a common issue towards the successful implementation of MCDMs.	Kolios (2011)
10	The extended TOPSIS method to solve multi-attribute group decision making problems in form of interval grey linguistic variables and attribute weight is unknown.	Jin and Liu (2010)
11	Presented a methodology to evaluate a number floating support structure configurations, for offshore wind turbines deployed in deep waters.	Martin (2010)
12	Used TOPSIS on energy policy objectives for sustainable development	Doukas (2010)
13	Formation of the integrated competitive strategy of an enterprise under the conditions of oligopoly market	Ginevicius (2010)

14	Determining the optional solution from the existing fleet	Čokorilo (2010)
15	Fuzzy AHP (FAHP) and the three MCDM analytical tools of SAW, TOPSIS, and VIKOR respectively adopted to rank the banking performance and improve the gaps with three banks	Wu (2009)
16	Selection of the most effective alternative in construction	Liaudanskiene (2009)
17	AHP and ELECTRE methods applied to assessment of E-banking Sector	Kaya and Kahraman (2011)
18	Investigating transport having complex interactions with the environment as an economic activity	Bojkovic (2010)
19	Solving Partner selection problem	Radziszewska-Zielina (2010)
20	Reveals influence of the choice of preference functions and their parameters on the outcome of evaluation	Podvezko and Podvezko (2010)
21	Assessed country-risk of sixteen Central, Baltic and South-East European transition countries, for 2005 and 2007, using multivariate cluster analysis	Tomić-Plazibat (2010)
22	Multi-criteria analysis was used to evaluate the integrated performance of silvoarable agro forestry on hypothetical farms in 19 landscape test sites in Spain.	Palma (2007)
23	Establishing Integrated competitive strategy of an enterprise under the conditions of oligopoly market. SAW, VIKOR and TOPSIS are used.	Ginevičius et al. (2010)
24	Implemented a fuzzy MCDM method, based on the AHP method, so as to find the optimum amongst energy policies in Turkey.	Kaya (2009)
25	AHP-based methodology applicable to problems where uncertain data were available, and the criteria weights are identified from the MCDM case.	Cobuloglu and Buyuktahtakın

26	Fuzzy AHP (FAHP) and the three MCDM analytical tools of SAW, TOPSIS, and VIKOR were respectively adopted to rank the banking performance and improve the gaps with three banks.	Wu (2009)
27	ELECTRE MCDM method was applied to select the optimum site location to install an offshore wind farm among four different choices/alternatives.	Ananda and Herath
28	ELECTRE method was applied to the optimization of decentralized energy systems.	Liu (2010)
29	Fuzzy VIKOR is applied in Modelling multidimensional redevelopment of derelict buildings.	Antucheviciene and Zavadskas (2008)
30	Assessment of regional and international development	Brauers (2010)
31	Evaluation of feasible alternatives and selection problem	Garcia Alcaraz et al. (2010)

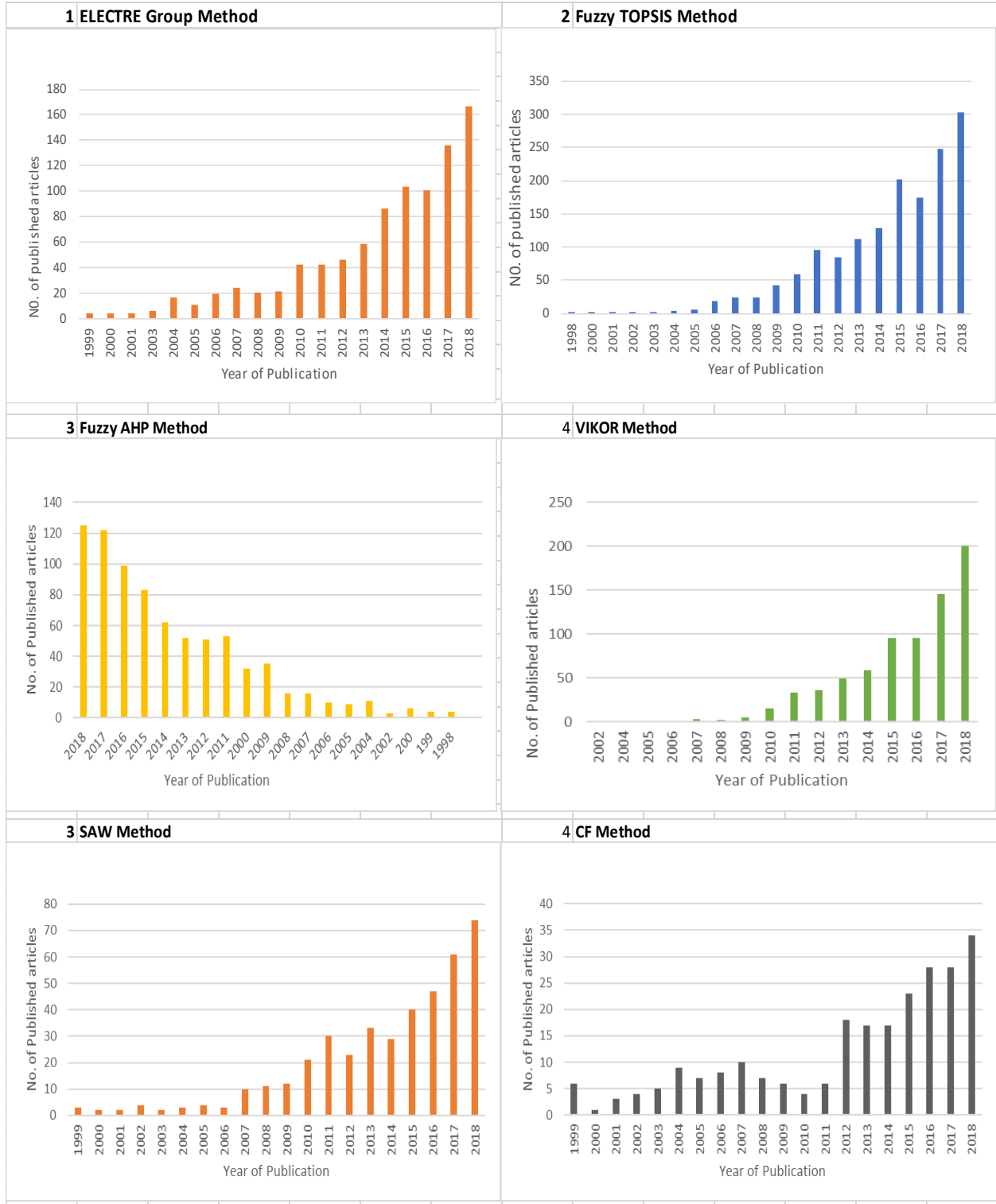


Figure 2: Published articles on MCDM methods

For the purpose of this study, different methods have been reviewed, which are applied in multi-criteria analysis problems. Comparatively the fuzzy approach gives the experts the freedom to express the different factors in numerical values, a range of numerical values, a linguistic term or a fuzzy number. In addition, the awareness and the use of MCDM tools in Ethiopian construction company's industry is very low. The fuzzy approach gives the respondents the freedom to express the Technology Transfer determinants in numerical values, a range of numerical values, a linguistic term or a fuzzy number. In addition, the respondent opinion depends on their experience and work they are practicing on the case study project. Hence, there are different criteria (Experts, Engineers & Laborers) for given alternatives of the determinants for technology transfer where each criterion (Experts, Engineers & Laborers) will be able to decide which factor is more important and prioritize accordingly. Since the respondent's level of understanding for the need of technology transfer as a whole for a given project (where there is a transferor and transferee), different weight must be given for each criterion. As shown in figure 2, Fuzzy TOPSIS & Fuzzy AHP has been used more often, and is growing throughout the years. This shows that the methods are more powerful in applying them on multi criteria decision maker problems. Therefore, for this study the fuzzy-TOPSIS approach and Fuzzy-AHP weighting approach is found to be more useful, due to existence of multi criteria that have different weight with different factors to be prioritized.

In this paper, determining the main factor of Technology Transfer, relating them with their importance range and explaining their importance on the stage of constructing a project, will focus on the case study of Commercial Bank of Ethiopia New Head quarter (CBEHQ) project. This project is the biggest high-rise project in Ethiopia so far with 4 basements and G + 48 floors with. This project is estimated to cost over 6 billion Ethiopian birr. The high-rise building project is number one in Ethiopia and ranked on third level throughout Africa. This project is the biggest asset for Ethiopia, since it is government owned project. The CBEHQ project construction is handled by the most known international contractor called China State Construction Engineering Corporation (CSCEC). CSCEC are worldwide known company with the largest transnational construction company in developing countries and the top home builder in the world. They are at the 14th level in the international construction industry (ZY Zhao, 2009). They work on the biggest construction projects This project is in number one stage building in Ethiopia and number three in Africa. The consulting is handled by the client's representative, Addis Ababa Institute of

Technology (AAiT). Hence this is one of the best opportunities for Ethiopia to participate on the technology and knowledge transfer. Even though the foreign contractors and local workers work together, there is a big gap in the process of technology transfer in this project. This can happen because of two reason, one is because the transferor is not willing to transfer the new technologies to the transferee and the second reason is due to the negligence of the transferee. This paper will center on determining the main factors for effective technology transfer for the use of upcoming different new projects in Ethiopia.

## **CHAPTER THREE**

### **RESEARCH DESIGN AND METHODOLOGY**

#### **3.1. Introduction**

This chapter will include the methodology used for this study. The discussion is designed on:

- Research design,
- Population sampling,
- Data collection and data analysis.

#### **3.2. Methodology**

The methodology selected for the study contains a comprehensive literature review, a questionnaire and interviewing the local consultant engineers of Addis Ababa Institute of Technology (AAiT) with the laborers and some of the project managers and local employees in China State Engineering Cooperation (CSCEC), a Multi criteria decision maker analysis of the survey data, and prioritization of the identified technology transfer factors/determinants.

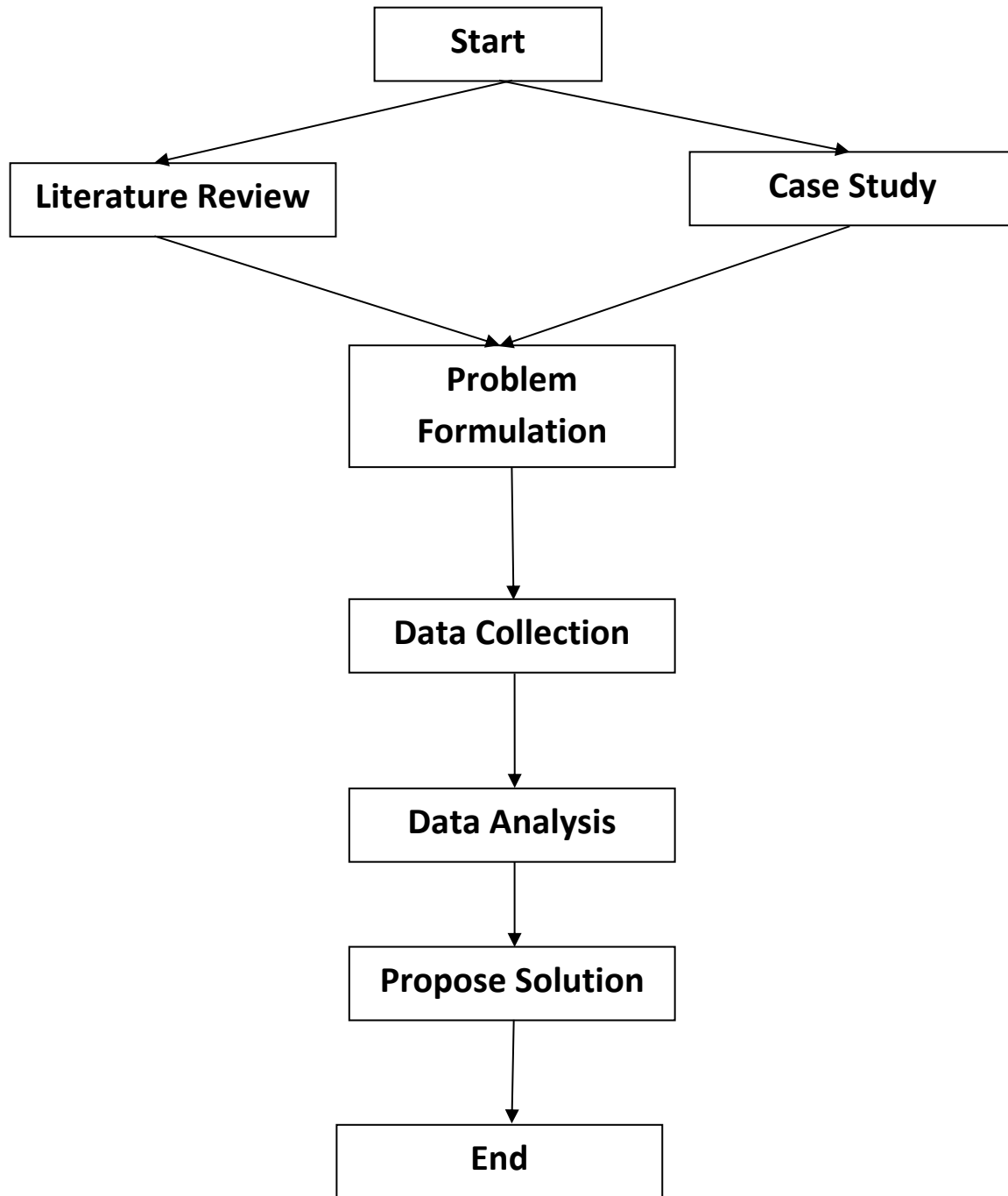


Figure 2: Research Design

### 3.3. Population

In this study, the population includes client and client representative 7 experts & 24 engineers, contractor’s (CSCEC’s) employees (7 engineers and 123 laborer) and CSCEC engineers and technicians in CBEHQ projects.

### 3.4. Sampling Approach

**Invalid source specified.** defined the sampling as the process of selecting representative units of a population for the study in a research investigation.

A non-probability purposive sampling design is used for the study. The participants met the eligibility a criterion as described in Table 7, was contacted, the purpose of the study explained and agreement to participate obtained. Since only Ethiopian Road Authority (ERA) represents the owner perspective, the researcher chose Top Management Personnel as participants because of a need for experts.

**Table 3: Respondents Criteria**

Criteria	Project Participant			Participant academic qualification	
	Local Client Representative	Local Employee of Contractors	Foreign Employee of the contractor	Local Client Representative & Local Employee of Contractors	Laborers
Range	Min 20	Min 5	Min 20	B.Sc. and Above	-

### 3.5. Data Collection

Data gathering is the core in doing a research which can be done with different techniques, such as: archival and institutional techniques, field collecting, internet, focus group, observation, projective techniques, panel studies and test marketing. It will help to design the research project and provide the background knowledge to confidently select and apply different methods with professional career. In this study data is gathered through a comprehensive literature review to

identify the major factors for technology transfer in construction industry, a closed-ended questionnaire to rank each factor and also to understand the barriers and enablers for the technology transfer. Interview was also taken to provide an explanation regarding the questionnaire and a situation where the laborers can express their intake from the foreign companies, and the gap where the technology transfer is missed and how to work on a strategy for the future work. Even though the factors has been determined, questionnaire which is used to check if there is a gap between the foreign contractor and the local firms and employees first.

### **3.5.1. Questionnaire Design**

The questionnaire survey is conducted to rank the major factors/determinants for technology transfer construction building where there are foreign transferor and local employees/clients as transferee. By evaluating or ranking each factor with regards to the experts, employed engineers and laborers opinion related with their field as well as concerns, a frame work is design for a future work. The frame work is based on relating the determined factors of technology transfer with the project life cycle in construction project. This will help to have a strategy of the process of successful technology transfer for a future construction project related with foreign contractor and local client-based project in Ethiopia. Furthermore, to use the opportunity of this kind of technology transfer from the foreign transferors to the local contractors & subcontractors and take advantage as being the host or owners.

The identified determinants/factors for technology transfer were taken from the experts, engineers and laborers aspects and importance. This includes clause related matters, training and practicing related matters for the laborers as well as the engineers and involvement of engineers related with engineering works. The details of each determinants/factors of technology transfer are shown in ANNEX 1.

A close-ended questionnaire was used since it is easy to ask and quick to answer, they require no writing by either respondents or interviewer unless they have additional comment. The questionnaire was composed of three sections to accomplish the aim of this research, as follows:

1. General information about the organization and respondents' profile (client/client representative, foreign contractors and local employees)
  - Academic qualification
  - Working experience in transferor and transferee related construction project.
  - Current job status
  - Professional background
  - Respondents project participation
  - New technology or knowledge practiced or learned as being a local firm from the foreign contractors (in general with regards to management, practical skill, engineering/technical skill, new techniques (tools & machineries) and design related)
  - Project involvement (client/client representative, contractor or contractor's local employee)
2. Level of knowledge or technology practiced by the foreign contractor on site was rated by the client representative employees and local employees of the foreign contractors, the local employees of both foreign contractor and client representative employees rated their experience and practice on CBEHQ project to understand how much they have actually learned or practiced the existing new technologies from the foreign contractors. And related the result with the ones that the foreign contractor gave the rating to the local employees. Five linguistic variables are used in describing parameter which is called the likelihood of occurrence (RL) and is indicated as Very Low, Low, Moderate, High, Very High

To ensure that complete and meaningful response to the questionnaire were obtained, an interview was conducted with each respondent to explain the objective of the study and to get input towards the questionnaire design, especially for the local laborers all the questions were held by taking an interview with cluster type.

### **3.6. Data Processing and Analysis**

Data analysis is a mechanism for reducing and organizing data to produce findings that require interpretation by the researcher

### 3.6.1. Multi Criteria-Based Decision Making (MCDM) and Fuzzy Set

Multi-Attribute Decision Making (MADM) or Multiple Criteria-based Decision Making (MCDM) is defined as making decisions in the presence of multiple set of criteria. The decision makers have to select, assess or rank these alternatives according to the weights of the criteria. In many real-world situations, the problems of decision making are subjected to some constraints, objectives and consequences that are not accurately known. Fuzzy sets within MCDM has been introduced for decision making in fuzzy environments. (After Bellman and Zadeh). The combination of MCDM and fuzzy set theory has led to a decision theory known as fuzzy multi criteria decision making (FMCDM) where decision maker models dealing with uncertain knowledge and information. When assessing or deciding in a quantitative matter and to express linguistic variables, fuzzy numbers are necessary.

Therefore, the first step in the development of a fuzzy set is creating a comprehensive list of evaluation criteria. In this case the evaluation criteria are linguistic variables used in describing the determinants/factors for technology transfer as shown in Table below.

**Table 4: Description of Linguistic variables**

Rating	Description	Likelihood
1	Very Low	Degree of the determinants is likely to have a very low rate for the success of technology transfer.
2	Low	Degree of the determinants is likely to have low rate for the success of technology transfer
3	Moderate	Degree of the determinants has a moderate rate for the success of technology transfer
4	High	Degree of the determinants has a high rate for the success of technology transfer
5	Very High	Degree of the determinants has a very high rate for the success of technology transfer

However, the fuzzy concept for this study is related with TOPSIS which can be described with two definitions.

1. A fuzzy set  $\tilde{a}$  in universe of discourse  $X$  is characterized by a membership function  $\mu_{\tilde{a}}(x)$  that maps each element  $x$  in  $X$  to a real number in the interval  $[0, 1]$ . The function value  $\mu_{\tilde{a}}(x)$  is termed the grade of membership of  $x$  in  $\tilde{a}$ . Nearer the value of  $\mu_{\tilde{a}}(x)$  to unity, higher will be the grade of membership of  $x$  in  $\tilde{a}$ .
2. A triangular fuzzy number is represented as a triplet  $\tilde{a} = (a,b,c)$ . The membership function  $\mu_{\tilde{a}}(x)$  of triangular fuzzy number  $\tilde{a}$  is given as:

$$\mu_{\tilde{a}}(x) = \begin{cases} \frac{x-a}{b-a} & \text{if } a \leq x \leq b \\ \frac{c-x}{c-b} & \text{if } b \leq x \leq c \\ 0 & \text{Otherwise} \end{cases}$$

Where  $a, b, c$  are real numbers and  $a < b < c$ .

The value of  $x$  at  $b$  gives the maximal grade of  $\mu_{\tilde{a}}(x)$ , i.e.,  $\mu_{\tilde{a}}(x) = 1$ ; it is the most probable value of the evaluation data. The value of  $x$  at  $a$  gives the minimal grade of  $\mu_{\tilde{a}}(x)$ , i.e.,  $\mu_{\tilde{a}}(x) = 0$ ; it is the least probable value of the evaluation data. Constants  $a$  and  $c$  are the lower and upper bounds of the available area for the evaluation data. These constants reflect the fuzziness of the evaluation data. The narrower the interval  $[a, c]$  the lower the fuzziness of the evaluation data.

### 3.6.2. Linguistic variables

Conversion scales are applied to convert the linguistic terms into fuzzy number in fuzzy set theory. In this study, a scale of 1 to 9 for rating the criteria and the alternatives is used (Buckley, 1985). The linguistic variables and fuzzy ratings for the alternatives and the criteria are as shown in Table-5.

**Table 5: Fuzzy Ratings for Linguistic Variables**

Fuzzy Number	Alternative Assessment
(1,1,3)	Very Low (VL)
(1,3,5)	Low (L)
(3,5,7)	Moderate (M)
(5,7,9)	High (H)

(7,9,9)

Very High (VH)

The values for the triangular fuzzy numbers that has been chosen above for the linguistic variables take into consideration the fuzziness and the distance among the variables as shown in equations 1 and 2. Hence, the intervals is written in a uniform representation from 1 to 9 for the fuzzy triangular numbers used for the five linguistic ratings.

### 3.6.3. FUZZY TOPSIS

As discussed in the previous chapter, Fuzzy-TOPSIS and Fuzzy-AHP weighting approach is found to be more useful, due to existence of multi criteria that have different weight with different factors to be prioritized. Fuzzy TOPSIS (Technique for Order Preference by Similarity to Ideal Situation) is a technique which is used to evaluate multiple alternatives against the selected criteria. (Prabhakar, 2010) Fuzzy TOPSIS is used in a scenario where performance value in decision matrix is not crisp numeric value but instead they are linguistic term which are given by the decision maker. An alternative that is nearest to the Fuzzy Positive Ideal Solution (FPIS) and farthest from the Fuzzy Negative Ideal Solution (FNIS) is chosen as optimal in TOPSIS. An FPIS includes the best performance values for each alternative and the FNIS is composed of the worst performance values. The steps of fuzzy TOPSIS as presented below.

Let's assume the decision group has M members.

The fuzzy rating of the  $m^{\text{th}}$  decision maker, about the  $i^{\text{th}}$  alternative on  $j^{\text{th}}$  criterion, are:

$$\tilde{x}_{ij}^m = (a_{ij}^m, b_{ij}^m, c_{ij}^m)$$

The importance weight of the  $m^{\text{th}}$  decision maker about the  $i^{\text{th}}$  alternative on  $j^{\text{th}}$  criterion, are:

$$\tilde{w}_j^m = (a_{ij}^m, b_{ij}^m, c_{ij}^m)$$

Where, where  $i = 1, 2, \dots, m$ , and  $j = 1, 2, \dots, n$ , then the aggregated fuzzy ratings  $\tilde{x}_{ij}$  of alternatives (i) with respect to each criterion (j) are given by  $\tilde{x}_{ij} = (a_{ij}, b_{ij}, c_{ij})$  such that:

$$a_{ij} = \min_m [a_{ij}^m], b_{ij}^m = \frac{1}{M} \sum_{m=1}^M b_{ij}^m, c_{ij} = \max_m [c_{ij}^m] \quad (\text{equation 1})$$

The aggregated fuzzy weights of each criterion are calculated as  $\tilde{w}'_j = (a'_j, b'_j, c'_j)$  where:

$$a'_j = \min_m [a_j'^m], b_j'^m = \frac{1}{M} \sum_{m=1}^M b_j'^k, c_{ij} = \max_m [c_j'^m] \quad (\text{equation 2})$$

A fuzzy multicriteria Group Decision Making (GDM) problem which can be concisely expressed in matrix format as:

$$\tilde{GD} \quad (\text{equation 3})$$

$$4) \quad \tilde{W}_4 = \begin{matrix} & & C_1 & C_2 & & C_n \\ \begin{matrix} A_1 \\ A_2 \\ \dots \\ A_m \end{matrix} & & \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & & \tilde{x}_{2n} \\ \dots & \dots & \tilde{x}_{ij} & \dots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & & \tilde{x}_{mn} \end{bmatrix} & & \end{matrix} = (\tilde{w}_1, \tilde{w}_2, \dots, \tilde{w}_n) \quad (\text{equation 4})$$

where for all  $\tilde{x}_{ij}$  and  $\tilde{w}_j$   $i = 1, 2, \dots, m; j = 1, 2, \dots, n$ . Here  $\tilde{x}_{ij} =$

$(a_{ij}, b_{ij}, c_{ij})$  and  $\tilde{w}_j = (a'_j, b'_j, c'_j)$  are triangular fuzzy numbers representing linguistic variables. To keep the normalization formula simple, the linear scale transformation is used to transform various criteria scales into a comparable scale. The normalization method preserves the property that the ranges of normalized triangular fuzzy numbers belong to  $[0,1]$ .

Thus, we have the normalized fuzzy decision matrix as:

$$\tilde{N} = (\tilde{n}_{ij})_{m \times n}, i = 1, 2, \dots, m; j = 1, 2, \dots, n \quad (\text{equation 4})$$

Where:

$$\tilde{n}_{ij} = \left( \frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*} \right) \text{ and} \quad (\text{equation 5})$$

$$c_j^* = \max_i c_{ij} \quad (\text{benefit criteria})$$

$$\begin{aligned}
 (\tilde{n}_{ij}) &= \left( \frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}} \right) \text{ and} \\
 a_j^- &= \min_i a_{ij} \text{ (cost criteria)}
 \end{aligned}
 \tag{equation 6}$$

The weighted normalized fuzzy decision matrix  $\tilde{N}w$  is computed by multiplying the weights ( $\tilde{w}_j$ ) of evaluation criteria with the normalized fuzzy decision matrix  $\tilde{n}_{ij}$  as:

$$\begin{aligned}
 \tilde{N}w &= [\tilde{n}w_{ij}]_{m \times n} \text{ where:} \\
 i &= 1, 2, \dots, m; j = 1, 2, \dots, n. \\
 \tilde{n}w_{ij} &= \tilde{n}_{ij} * \tilde{w}_j = (a''_{ij}, b''_{ij}, c''_{ij})
 \end{aligned}
 \tag{equation 7}$$

weights ( $\tilde{w}_j$ ), can be calculated using Fuzz AHP logic instead of assuming the weights of each criteria given.

Fuzzy AHP weight calculation can be determined:

The FPIS and FNIS of the alternatives are defined as follows:

$$\begin{aligned}
 A^* &= (\tilde{v}_1^*, \tilde{v}_2^*, \dots, \tilde{v}_n^*) \text{ where} \\
 \tilde{v}_j^* &= (c, c, c) \text{ such that:} \\
 c &= \max_i [c''_{ij}], i = 1, 2, \dots, m; j = 1, 2, \dots, n.
 \end{aligned}
 \tag{equation 8}$$

$$\begin{aligned}
 A^- &= (\tilde{v}_1^-, \tilde{v}_2^-, \dots, \tilde{v}_n^-) \text{ where} \\
 \tilde{v}_j^- &= (a, a, a) \text{ such that:} \\
 a &= \min_i [a''_{ij}], i = 1, 2, \dots, m; j = 1, 2, \dots, n.
 \end{aligned}
 \tag{equation 9}$$

The distance ( $d_i^*$  and  $d_i^-$ ) of each weighted alternative  $i = 1, 2, \dots, m$  from the FPIS and the FNIS is computed as follows:

$$d_i^* = \sum_{j=1}^n d_v(\tilde{v}_{ij}, \tilde{v}_j^*), i = 1, 2, \dots, m \quad (\text{equation 10})$$

$$d_i^- = \sum_{j=1}^n d_v(\tilde{v}_{ij}, \tilde{v}_j^-), i = 1, 2, \dots, m \quad (\text{equation 11})$$

where  $d_v(\tilde{a}, \tilde{b})$  is the distance measurement between two fuzzy numbers  $\tilde{a}$  and  $\tilde{b}$ .

The closeness coefficient  $cc_i$  represents the distances to fuzzy positive ideal solution,  $A^*$ , and the fuzzy negative ideal solution,  $A^-$  simultaneously. The closeness coefficient of each alternative is calculated as:

$$cc_i = \frac{d_i^-}{d_i^- + d_i^*}, i = 1, 2, \dots, m \quad (\text{equation 12})$$

The alternative with highest closeness coefficient represents the best alternative and is closest to the FPIS and farthest from the FNIS.

In summary, the TOPSIS steps that we use are as follows:

- i. Aggregate the weight of criteria to get the aggregated fuzzy weight  $\tilde{w}_j$  of criterion  $C_j$  (using equation 2) and pool the decision makers' ratings to get the aggregated fuzzy rating  $\tilde{x}_{ij}$  of alternative  $A_i$  under criterion  $C_j$  (using equation 1).
- ii. Construct the fuzzy decision matrix and the normalized fuzzy decision matrix (equations 5, 6 and 7).
- iii. Construct the weighted normalized fuzzy decision matrix (equation 8).
- iv. Determine FPIS and FNIS and calculate the distance of each alternative from FPIS and FNIS, respectively (equations 9, 10, 11 and 12).
- v. Calculate the closeness coefficient of each alternative and rank the alternatives (equation 15).

## **CHAPTER FOUR**

### **DATA PRESENTATION AND ANALYSIS**

#### **4.1 Data Presentation**

The main determinants/factors for the success of technology transfer from transferor to transferee in construction projects were identified through literature review and questionnaire survey. The questionnaires were targeted at experienced respondents, engineers and laborers from both the client (CBE)/client representative (AAiT) and contractors (CSCEC). The questions for the survey were structured based on the information gathered through literature review. The main purpose was to identify and rank the main factors that leads to a successful technology transfer and construct a strategy taking the determinants and relating them with project life cycle for a future construction project.

##### **4.1.1 Contents of the Questionnaire**

For the purpose of the survey, the main determinants/factors that affect technology transfer in a construction projects were identified through literature review. An extensive literature review was made to understand the process of technology transfer from developed countries to developing countries and what the major factors are for the success of the transfer. Based on the review, 18 determinants/factors were identified as tabulated Before identifying and ranking the determinants a questionnaire was distributed for the local employees both on the client representative side and the contractor side. The questionnaire relies on judging the foreign contractors experience on CBEHQ project related with the extent of the foreign contractor's knowledge and skills, knowledge and technology sharing and how much the employees have learned from them and if not, identifying where the gap is. The capacity of the local employees of accepting and experiencing the new technology has also been judged by the contractor's experts ANNEX 1

##### **4.1.2 Target Population**

The ranking and prioritization of the determinants/ factors was carried out from the perspective of a client representative employees (experts & engineers) and local employees (engineers and laborers) from the foreign contractors who met the minimum criteria as shown in Table 6. In

addition to that, to check if the local employees on site are capable of accepting and understanding the new technology that is being experienced on site, questionnaire for the experts, engineers and technicians from CSCEC has been distributed as shown on ANNEX 1.

The survey was made from client representative 6 management and contract experts and 26 engineers from every field (Mechanical, Electrical, plumbing & firefighting, structural & material civil engineers), 13 experts & 19 technicians from foreign contractors and 112 employed laborers of the contractor, related with the capacity of the foreign contractors, their experience of sharing knowledge, new techniques & skills, and at last the capacity of laborers on understanding and accepting the new technology. Before the questionnaires were distributed to each respondent, a quick briefing was made to explain the context of the questionnaire regarding the objective of the thesis.

**Table 6: Company Profile of Respondents of the client representative (AAiT)**

Role	Work Position Of Respondents	No	Educational Background	No	Professional Background Of The Respondents	No	Work Experience	No
	Resident Engineer	1	PHD	2	Civil engineer (structural & material)	16	> 5 years	18
Client representative	Contract expert	3	MSc	9	Mechanical Engineer	2	2-5 years	6
	Office Engineer	3	BSc	13	Electrical Engineer	2		
	Civil Supervision Team	7			Architect	2		
	Quantity surveyor & cost Engineer	2	other	-				
	Mechanical Supervision Team	2						
	Electrical Supervision Team	2						
	Plumbing & Firefighting supervision team	1						
	Surveyor	1						
	Architect	2						

**Table 7: Company Profile of Respondents of the Contractors (CSCEC)**

Role	Work Position Of Respondents	No	Educational Background	No	Professional Background Of The Respondents	No	Work Experience	No
	General Manager	1	PHD	-	Civil engineer (structural & material)	8	> 5 years	33
Contractors (CSCEC)	Contract expert	1	MSc	-	Mechanical Engineer	3	< 5 years	142
	Office Engineer	1	BSc	10	Electrical Engineer	1		
	Civil Engineer & Supervision Team	5			Architect	1		
	Mechanical Plumbing & Firefighting Engineer	3	other	19				
	Electrical Supervision Team	1						
	Surveyor	1						
	Architect	1						
	Technicians	19						
Contractors/local Employees	Civil Supervision Team	5	MSc	-	Civil engineer (structural & material)	5	2-5 years	7
	Mechanical Plumbing & Firefighting Engineer	1	BSc	10	Mechanical Engineer	1		
	Electrical Supervision Team	1			Electrical Engineer	1		
	Laborers	123	other	142				

After the questionnaire has been distributed, some of the respondents were not able to respond. The number of questionnaires sent and number of the responses related with its rate is shown in table

**Table 8: Questionnaire Return Rate**

Role	Number of questionnaires sent/asked	Number of responses received	Response rate (%)	Number of questions sent	Number of responses received	Response rate (%)
Client Representative	28	24	85.7	33	33	100
Contractor						
➤ Experts	14	14	100.0	7	7	100
➤ Technicians	24	19	79.2	7	7	100
➤ Local Engineers	7	7	100.0	33	33	100
➤ Local Laborers	123	112	91.1	30	27	90

Before questioner has been distributed to rank the important factors for the success of technology transfer by the respondents, the study has tried to get information by informally interviewing the

workers, about whether there is a technology transfer or not in the case study of commercial Bank of Ethiopia (CBE HQ) project. Even though there are new machineries, tools & techniques in the project, the workers addressed that there has not been a successful means of technology transfer and no trainings has been given except for the workers who operates some of the machineries. And if there is not, to identify where the gap is. Hence questionnaire for both the Transferor (China State Construction Engineering Cooperation) and for the transferee which are: employee of China State Construction Engineering Cooperation (Both local engineers and local laborers) and employee of client representative (Experts & Engineers, Supervision teams) was distributed. The result showed that on both side that there is a gap on the process of Technology Transfer.

1. Transferee (Engineers) opinion about the transferor

Local Engineers (Transferee) from both the client representative and foreign contractor were able to identify weather the local foreign contractor (Transferor) willing to teach, train, share and communicate smoothly with the workers.

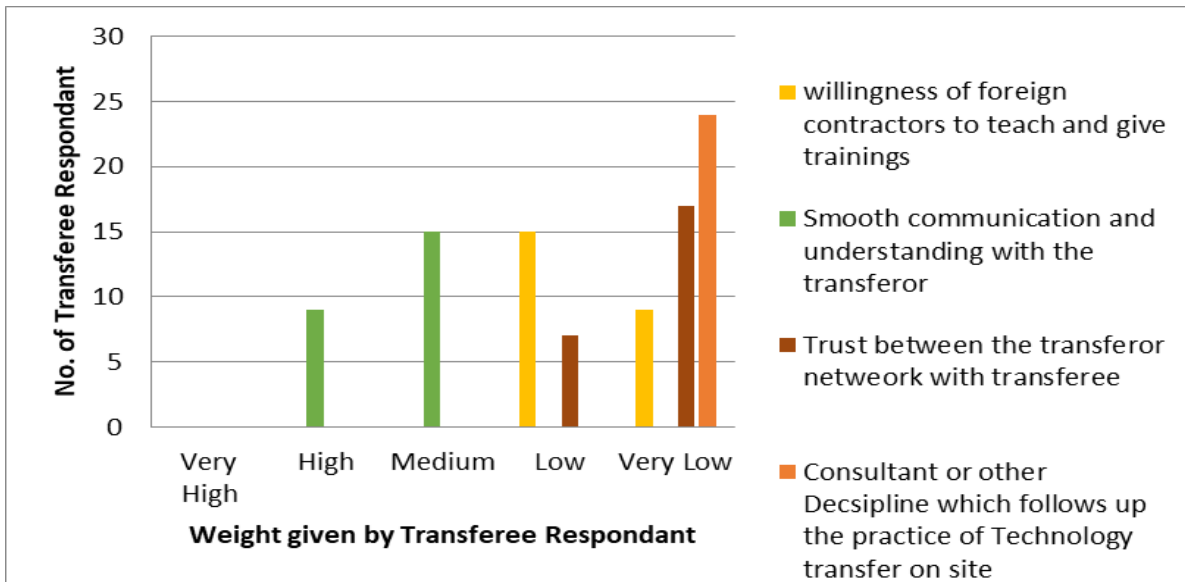


Figure 3: Transferee opinion (Rate) about the transferor

As the result shows from the graph above, the transferee respondent believes that the weight on the existence of consultant or other disciplines which follows up the practice of technology transfer, the foreign contractors to teach and give trainings, the smooth communication between

the transferor and transferee and the trust between them is very low. This shows that the existence of barriers for technology transfer.

### 2. Transferee opinion about the transferor (From the Laborers)

Local Laborers, employees (Transferee) from foreign contractor were able to identify weather the local foreign contractor (Transferor) willing to teach, train, share and communicate smoothly with the workers.

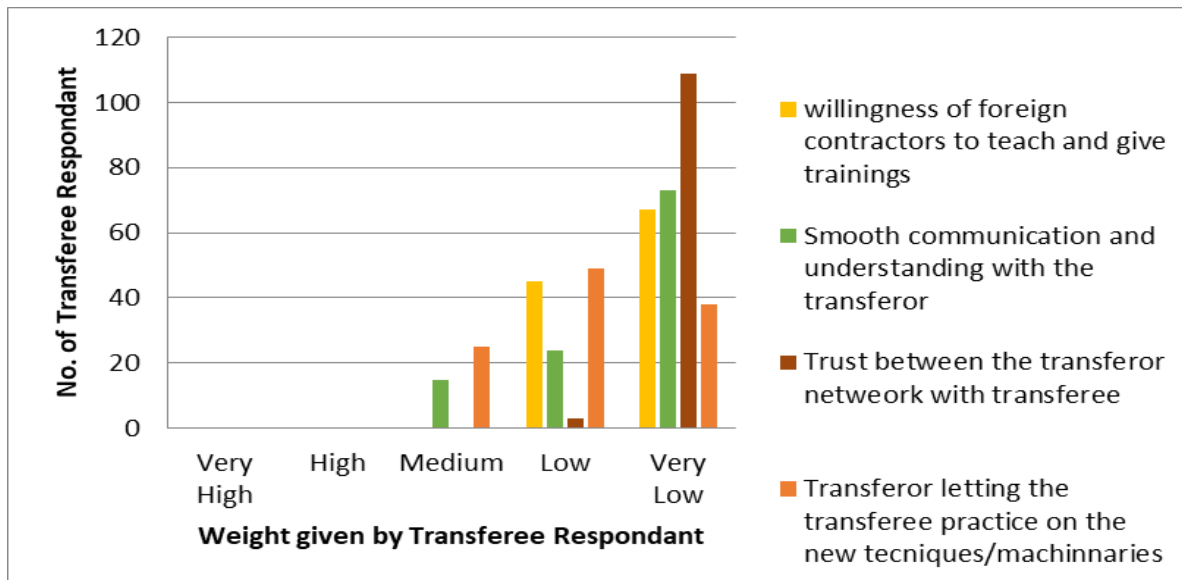
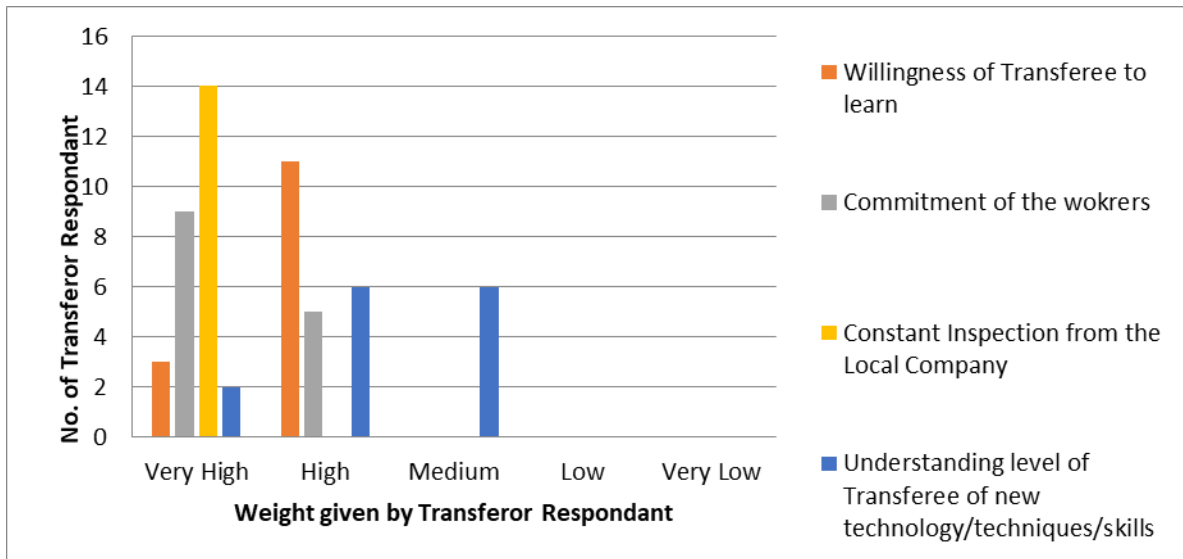


Figure 4: Transferee opinion (Rate) about the transferor

From the above result, it shows that the commitment of the local workers is rated in between very high and high, the willingness of the transferee to learn on site is rated between very high to medium, the understanding level of the transferee is rated between medium & low and the constant inspection from the local employees of the client representative of the work is rated very high.

### 3. Transferor opinion about the transferee (From the Experts)

Experts from the transferor side were able to identify weather the local employees have the capacity to accept and learn new technologies during the inspection process, and if there is a constant inspection of the work from the local employees of the client representative.

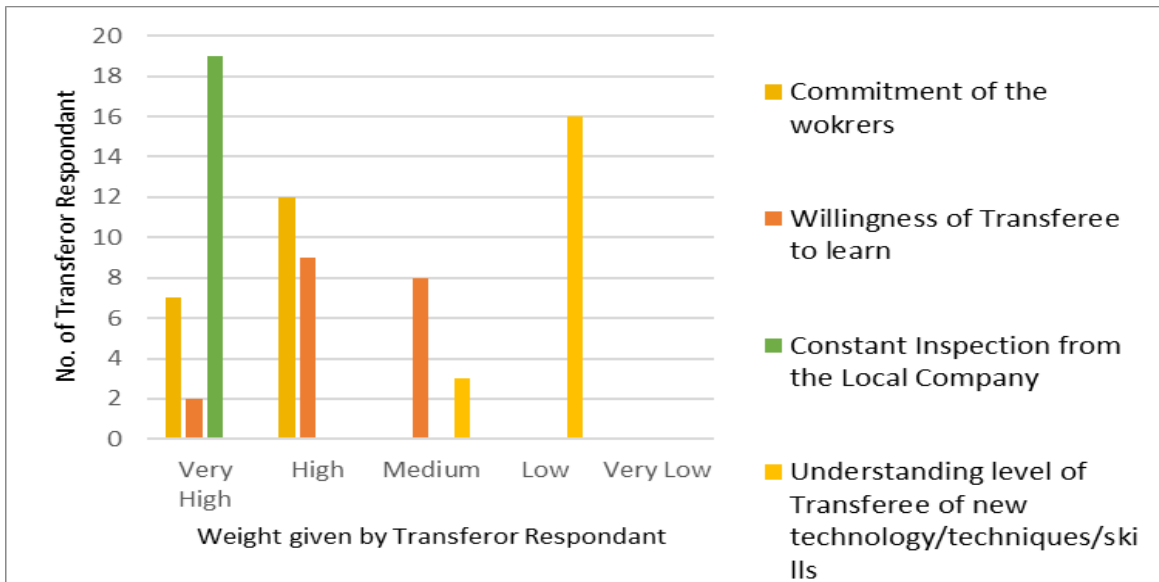


**Figure 5: Transferor opinion (Rate) about the transferee (From the Experts)**

From transferor opinion about the transferee, the level of constant inspection from the local company, the commitment of the workers, and the willingness of transferee to learn shows form very high to medium range. Hence even if there are different barriers for the success of technology transfer to exist on this particular project, the local workers (transferee) are ready to learn and develop their knowledge from the foreigner contractor (transferor).

#### 4. Transferor Opinion about the transferee (From Technicians View)

Technicians from the transferor side were able to identify whether the local employees have the capacity to accept and learn new technologies during the inspection process, and if there is a constant inspection of the work from the local employees of the client representative.



**Figure 6: Transferor opinion (Rate) about the transferee (From Technicians View)**

On figure 6, it shows that the commitment of the local workers is rated in between very high and high, the willingness of the transferee to learn on site is rated between very high to medium, the understanding level of the transferee is rated between medium & low and the constant inspection from the local employees of the client representative of the work is rated very high.

The response from both the foreign contractor (transferor) and the local workers (transferee) shows that even though there is a constant inspection of the work, and there is commitment of the workers to learn more, there has not been a good means of technology transfer. This is due to communication problem, the transferee not willing to teach, unexperienced local workers, and also there is no strategy which follows up the process of technology transfer. Hence, this study tried to identify factors/ determinants for the success of technology transfer from literature review and then questionnaire was developed to both the local employees of the foreign contractor and the local client representatives to rate their opinion on the identified factors for technology transfer with regard to their work experience. This is important because with their own experience from working on this specific project (CBE HQ), they will be able to identify their gap and rate the importance of each determinants.

**Table 9: Number of decision makers (related with their criteria) rating the alternatives (Determinants/Factors)**

No.	Determinants of technology transfer (Alternatives)	Engineers (Criteria 1)					Experts (Criteria 2)					Laborers (Criteria 3)				
		VL	L	M	H	VH	VL	L	M	H	VH	VL	L	M	H	VH
1	Need of previous experience of the local workers in working with international contractors		3	4	6	12				3	3				42	70
2	Transferor allowing the transferee to practice the new techniques on site		2	5	7	11				3	3				18	94
3	Transferor training the transferee for the expected work			3	6	16				1	5			41	42	29
4	Involvement of Local Experts on Design stage of the project	3	6	3	2	11				2	4			52	26	34
5	Smooth communication between the Transferee and Transferor		6	14	5				3	3				24	38	50
6	Team work between the foreign and local firm			2	11	12				5	1			38	39	35
7	Involving constant supervision and inspection team from local company			2	8	15				2	4			55	34	23
8	Need of specific discipline which follows up the effectiveness of technology transfer on site		3	5	7	10				5	1	4	48	44	16	
9	Thorough visitation of local contractors to learn and get experience		3	2	10	9				4	2			4	60	48

10	Involving local institutes to participate for the purpose of learning and do research	12	10	3	2	4	28	35	38	11
11	Need of government enforcement (regarding on design, installation and contract agreement) for the knowledge and technology transfer	9	13	3	3	3	22	56	34	
12	Including a section in initial contract, which insist on for all the local parties to get involved in the project with foreign contractors		19	6		6		36	52	24
13	Hiring experienced local technicians with capacity and technical skills		4	21	5	1			43	69
14	Willingness of Transferor to teach and give trainings to the local employees	3	9	13	4	2			41	71
15	Need of trust within the transferee and transferor	16	9		3	3		65	33	14
16	Transferee commitment to learn and practice on site		18	7		6			96	16
17	Need of experienced expertise and engineers for the success of technology transfer	8	6	11	2	4		33	71	8
18	Local sub-contractor involvement on the project		3	22		1	5	19	59	34

Table 9 shows, the number of decision makers (related with their criteria) rating the alternatives (Determinants/Factors). Each decision makers (Local Experts, Engineers and Laborers) gave their opinion on how each determinant are important for the success of technology transfer on the project as per their work experience. The importance of each determinant is ranged using the likelihood (from very high, high, medium, low to very low). Once the decision makers rate their opinions within the given range, then the next step is constructing a fuzzy set.

## 4.2 Data Analysis

In this section, fuzzy set is constructed by converting the linguistic variables to fuzzy sets and then aggregated fuzzy ratings is calculated. Once the aggregated fuzzy ratings are determined, the fuzzy decision matrix and normalized fuzzy decision matrix is calculated and then weighted. The next step is determining the fuzzy positive ideal solution (FPIS) and fuzzy negative ideal solution (FPNS) and calculating the distance of each alternative from FPIS and FNIS. The last step is calculating the closeness coefficient of each alternative and ranking the alternatives.

### 4.2.1 Development of fuzzy set

The respondents rate the given alternatives (determinants/factors for technology transfer), on the given 5-point scale (which is Very high, High, Moderate, Low and Very low). This linguistic variable is converted to a scale of 1-9 for rating the alternative with the criteria. For the five linguistic ratings, the intervals are chosen since they have a uniform representation from 1 to 9 for fuzzy triangular numbers. The linguistic variables and the fuzzy ratings for the alternatives and criteria are shown below in table10.

**Table 10: Fuzzy ratings for linguistic variables**

No.	Linguistic Variables	Fuzzy Number (a, b, c)
1	Very Low (VL)	(1,1,3)
2	Low (L)	(1,3,5)
3	Moderate (M)	(3,5,7)

4	High (H)	(5,7,9)
5	Very High (VH)	(7,9,9)

5 After the fuzzy rating has been determined for the linguistic variables, the next step is to combine the decision makers' ratings to get the aggregated fuzzy rating  $\tilde{x}_{ij}$  of alternative  $A_i$  under criterion  $C_j$ . This is calculated by using equation for  $\tilde{x}_{ij} = (a_{ij}, b_{ij}, c_{ij})$ .

**Table 11: Fuzzy rating for Determinant/Factor 1**

No.	Determinants of technology transfer (Alternatives)	Engineers (Criteria 1)			
		3 Engineers	4 Engineers	6 Engineers	12 Engineers
1	Need of previous experience of the local workers in working with international contractors	(1,3,5)	(3,5,7)	(5,7,9)	(7,9,9)

No.	Determinants of technology transfer (Alternative 1)	Experts (Criteria 2)	
		3 Experts	3 Experts
1	Need of previous experience of the local workers in working with international contractors	(5,7,9)	(7,9,9)

No.	Determinants of technology transfer (Alternative1)	Laborers (Criteria 3)	
		42 Engineers	70 Engineers
1	Need of previous experience of the local workers in working with international contractors	(5,7,9)	(7,9,9)

$$\tilde{x}_{ij} = (a_{ij}, b_{ij}, c_{ij})$$

Where:  $\tilde{x}_{ij}$  = the aggregated fuzzy ratings of the given alternatives

$$a_{ij} = \min_m [a_{ij}^m], b_{ij}^m = \frac{1}{M} \sum_{m=1}^M b_{ij}^m, c_{ij} = \max_m [c_{ij}^m]$$

$$a_{ij} = \min_m [a_{ij}^m], \text{ minimum rate from } (1,3,5,7) = 1$$

$$a_{ij} = 1$$

$$b_{ij} = \frac{1}{M} \sum_{m=1}^M b_{ij}^m \left( \frac{(3*3)+(4*5)+(6*7)+(12*9)}{25} \right) = 7.16$$

$$b_{ij} = 7.16$$

$$c_{ij} = \max_m [c_{ij}^m] \text{ maximum rate from } (5,7,9) = 9$$

Hence, the aggregated fuzzy rating for alternative 1 with respect to criteria 1(Engineers) is (1,7.16,9). The same equation is used to find the fuzzy aggregated rating for alternative 1 with respect to 2 & 3.

$$a_{ij} = \min_m [a_{ij}^m], \text{ minimum rate from } (5,7) = 5$$

$$a_{ij} = 1$$

$$b_{ij}^m = \frac{1}{M} \sum_{m=1}^M b_{ij}^m \left( \frac{(3*7)+(3*9)}{6} \right) = 8$$

$$b_{ij}^m = 7.16$$

$$c_{ij} = \max_m [c_{ij}^m] \text{ maximum rate from } (9,9) = 9$$

Criteria 3 (Laborers)

$$a_{ij} = \min_m [a_{ij}^m], \text{ minimum rate from } (5,7) = 5$$

$$a_{ij} = 1$$

$$b_{ij}^m = \frac{1}{M} \sum_{m=1}^M b_{ij}^m \left( \frac{(4*7)+(70*9)}{112} \right) = 8.25$$

$$b_{ij}^m = 7.16$$

$$c_{ij} = \max_m [c_{ij}^m] \text{ maximum rate from } (5,7,9) = 9$$

**Table 12: Aggregated fuzzy rating for Determinant/Factor 1 relative to criteria 1,2 & 3**

No.	Determinants of technology transfer (Alternative1)	Engineers	Experts	Laborers
1	Need of previous experience of the local workers in working with international contractors	(1,7.16,9)	(5,8,9)	(5,8.25,9)

6 Constructing the fuzzy decision matrix and the normalized fuzzy decision matrix for the given determinants (using equation for  $\tilde{N}$ ).

$$\tilde{N} = (\tilde{n}_{ij})_{m \times n}, i = 1, 2, \dots, m; j = 1, 2, \dots, n$$

Where:  $\tilde{N}$  = normalized fuzzy decision matrix.

Here, all the alternatives (determinants) given are benefit for the success of technology transfer. Hence, the benefit criteria is only considered.

$$(\tilde{n}_{ij}) = \left( \frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*} \right) \text{ and}$$

$$c_j^* = \max_i c_{ij} \text{ (benefit criteria)}$$

For Alternative 1 (Transferor training the transferee for the expected work), relative to criteria 1, criteria 2 & criteria 3 the Aggregated fuzzy rating is determined as follows.

$$a_{ij}, b_{ij}, c_{ij} = (1,7.16,9), (5,8,9) \text{ and } (5,8.25,9)$$

$$c_j^* = \max_i c_{ij} = 9$$

For Determinant/Factor 1 with respect to criteria 1 (Engineers), the normalized fuzzy decision matrix is calculated as:

$$(\tilde{n}_{ij}) = \left(\frac{1}{9}, \frac{7.16}{9}, \frac{9}{9}\right) = (0.11, 0.8, 1)$$

For Determinant/Factor 1 with respect to criteria 2 (Experts) the normalized fuzzy decision matrix is calculated as:

$$(\tilde{n}_{ij}) = \left(\frac{1}{9}, \frac{7.16}{9}, \frac{9}{9}\right) = (0.56, 0.89, 1)$$

For Determinant/Factor 1 with respect to criteria 3 (Laborers) the normalized fuzzy decision matrix is calculated as:

$$(\tilde{n}_{ij}) = \left(\frac{1}{9}, \frac{7.16}{9}, \frac{9}{9}\right) = (0.56, 0.92, 1)$$

**Table 13: Normalized fuzzy decision matrix for Determinant/Factor 1 with respect to each criterion**

No.	Determinants of technology transfer (Alternative1)	Engineers	Experts	Laborers
1	Need of previous experience of the local workers in working with international contractors	(0.11,0.8,1)	(0.56,0.89,1)	(0.56,0.92,1)

7 Constructing the weighted normalized fuzzy decision matrix (equation 10): here each respondent was able to rate the determinants with regard to their experience and field which they think is more important. In order to identify the weight of each criteria, a Fuzzy AHP weight calculation has been taken. This will help to differentiate the weight of the Experts, the Engineers and the Laborers in the given project. Experts, work on starting from the contract agreement to the site work to be inspected and have the capacity to see and determine the project work from the beginning of the contract until the end of the project. The site engineers role on a given project is to assess the work which is being done on the site as well as to check on the laborer’s work and the laborers job is to work on the technical work on site. Hence the weight relies more on the experts then to the engineers and then to the laborers.

Taking this to account, a relationship matrix to determine the weight of each criteria is calculated using the Fuzzy AHP (Analytic Hierarchy Process) weight calculation.

Fuzzy AHP weight Calculation:

a. Construct Pair wise comparison matrix with the help of scale of relative importance

Fuzzified		
1	(1,1,1)	Equal importance
3	(2,3,4)	Moderate importance
5	(4,5,6)	Strong importance
7	(6,7,8)	Very strong importance
9	(9,9,9)	Extreme importance
Intermediate value		
2	(1,2,3)	
4	(3,4,5)	
6	(5,6,7)	
8	(7,8,9)	

b. Relationship matrix between the criteria

	Criteria 1	Criteria 2	Criteria 3
Criteria 1	(1,1,1)	(1/7,1/6,1/5)	(4,5,6)
Criteria 2	(5,6,7)	(1,1,1)	(6,7,8)
Criteria 3	(1/6,1/5,1/4)	(1/8,1/7,1/6)	(1,1,1)

c. Calculating the Fuzzy Geometric mean value

$$(r_1 * r_2 * r_3) = (l_1, m_1, h_1) * (l_2, m_2, h_2) * (l_3, m_3, h_3)$$

Then Calculating  $((l_3 * m_3 * h_3), (l_2 * m_2 * h_2), (l_1 * m_1 * h_1))^{1/4}$  and then adding the lower result, the middle result and the higher result of each criteria and then taking the reciprocal result.  $((r_1 * r_2 * r_3)^{1/4})^{-1}$ , The result is added with each fuzzy geometric mean value of the lower number (l), middle number (m) and the higher number (h).

Weight ( $\tilde{w}_i$ )

Criteria 1	0.282087447
Criteria 2	0.259403372
Criteria 3	0.238663484

The weighted normalized fuzzy decision matrix  $\widetilde{Nw}$  is computed by multiplying the weights ( $\widetilde{w}_i$ ) of evaluation criteria with the normalized fuzzy decision matrix  $\widetilde{n}_{ij}$  as:

$$\widetilde{Nw} = [\widetilde{nw}_{ij}]_{m \times n} \text{ where: } i = 1, 2, \dots, m; j = 1, 2, \dots, n$$

$$\widetilde{nw}_{ij} = \widetilde{n}_{ij} * \widetilde{w}_j = (a''_{ij}, b''_{ij}, c''_{ij})$$

$$\widetilde{nw}_{ij} = (0.282, 0.2594, 0.2386) * (0.11, 0.8, 1), (0.282, 0.2594, 0.2386) * (0.56, 0.89, 1), (0.282, 0.2594, 0.2386) * (0.56, 0.92, 1)$$

$$(a''_{ij}, b''_{ij}, c''_{ij}) = (0.02, 0.2, 0.29), (0.30, 0.0.58, 0.76), (0.049, 0.095, 0.126)$$

8 Next the fuzzy positive ideal solution (FPIS) and the fuzzy negative ideal solution (FNIS) is determined for each determinant/factor, then the distance of each alternative from FPIS and FNIS, respectively is calculated.

Using equations for  $A^*$ ,  $A^-$

$$A^* = (\widetilde{v}_1^*, \widetilde{v}_2^*, \dots, \widetilde{v}_n^*)$$

Where  $A^*$  is determined by taking the maximum rate of the  $c''_{ij}$  and the set is taken as a FPIS matrix result. If the maximum rate of  $c''_{ij}$  is the same, then the maximum rate of  $b''_{ij}$  is looked up on for next decision.

Where:  $a''_{ij}, b''_{ij}, c''_{ij}$  are the determined normalized fuzzy decision matrixes

$\widetilde{v}_j^* = (a, b, c)$  such that:

$$c = \max_i [c''_{ij}], i = 1, 2, \dots, m; j = 1, 2, \dots, n.$$

Where:  $c''_{ij}$  = for Alternative 1, (0.02, 0.2, 0.29), (0.30, .58, .76), (0.049,0.095,0.126), the maximum  $c''_{ij}= 1$ , which shows the three sets have the same rate, then the maximum rate of  $b''_{ij}$  is 0.76. Hence, the third set is chosen as a result.

$$\tilde{v}_j^* = (a, b, c) = (0.30, 0.58, 0.76)$$

$\tilde{v}_j^*$  is determined for all the alternatives taking the same procedure.

$$A^- = (\tilde{v}_1^-, \tilde{v}_2^-, \dots, \tilde{v}_n^-) \text{ where}$$

$\tilde{v}_j^- = (a, b, c)$  such that:

$$a = \min_i [a''_{ij}], i = 1,2, \dots, m; j = 1,2, \dots, n.$$

For Alternative 1, (0.02, 0.2, 0.29), (0.30, .58, .76), (0.049,0.095,0.126), the minimum  $a''_{ij}= 0.02$ , hence, the first set is chosen as a result.

$$\tilde{v}_j^- = (0.02, 0.2, 0.29)$$

**Table 14: FPIS & FNIS**

No.	Determinants of technology transfer (Alternative1)	FPIS (A*)	FNIS (A-)
1	Need of previous experience of the local workers in working with international contractors	(0.30, 0.58, 0.76)	(0.02, 0.2, 0.29)

Once the FPIS and FNIS is determined, the distance ( $d_i^*$  and  $d_i^-$ ) of each weighted alternative  $i = 1,2, \dots, m$  is computed from FPIS and FNIS using the vertex method equation as follows:

	Determinants of technology transfer (Alternative1)	Engineers	Experts	Laborer
1	Need of previous experience of the local workers in working with international contractors	(0.11,0.8,1)	(0.56,0.89,1)	(0.56,0.92,1)
2	(A*)	(0.30, 0.58, 0.76)		

---

3	(A <sup>-</sup> )	(0.02, 0.2, 0.29)
---	-------------------	-------------------

---

The distance from the FPIS of each alternative with respect to the criteria can be calculated as follows:

$$d_i^* = \sum_{j=1}^n d_v(\tilde{v}_{ij}, \tilde{v}_j^*), i = 1, 2, \dots, m$$

where  $d_v(\tilde{a}, \tilde{b})$  is the distance measurement between two fuzzy numbers  $\tilde{a}$  and  $\tilde{b}$ .

$$d_v = \sqrt{\frac{1}{3}[(a - a')^2 + (b - b')^2 + (c - c')^2]}$$

For criteria1 (Engineers),  $d_v = \sqrt{\frac{1}{3}[(0.11 - 0.3) + (0.8 - .58) + (1 - 0.76)]^2}$

$$d_v = 0.38$$

For criteria 1 (Experts),  $d_v = \sqrt{\frac{1}{3}[(0.56 - 0.3) + (0.89 - .58) + (1 - 0.76)]^2}$

$$d_v = 0.0$$

For criteria 3 (Laborers),  $d_v = \sqrt{\frac{1}{3}[(0.56 - 0.3) + (0.92 - 0.58) + (1 - 0.76)]^2}$

$$d_v = 0.48$$

$$d_i^* = \sum_{j=1}^n d_v(\tilde{v}_{ij}, \tilde{v}_j^*) = 0.27+0.2 = 0.87$$

The distance from the FNIS of each alternative with respect to the criteria can be calculated as follows

$$d_i^- = \sum_{j=1}^n d_v(\tilde{v}_{ij}, \tilde{v}_j^-) = (0.02, 0.2, 0.29)$$

For criteria 1 (Engineers),  $d_v = \sqrt{\frac{1}{3}[(0.11 - 0.02) + (0.8 - 0.2) + (1 - 0.29)]^2}$

$$d_v = 11$$

For criteria 1 (Experts),  $d_v = \sqrt{\frac{1}{3}[(0.56 - 0.02) + (0.89 - 0.2) + (1 - 0.29)]^2}$

$$d_v = 0.49$$

For criteria 3 (Laborers),  $d_v = \sqrt{\frac{1}{3}[(0.56 - 0.02) + (0.92 - 0.2) + (1 - 0.29)]^2}$

$$d_v = 0.02$$

$$d_i^* = \sum_{j=1}^n d_v(\tilde{v}_{ij}, \tilde{v}_j^*) = 0.27+0.27 = 0.62$$

**Table 15: The distance of Alternative1 from the FNIS & FPIS**

No.	Determinants of technology transfer (Alternative 1)	dv*	dv-	d <sub>i</sub> <sup>*</sup>	d <sub>i</sub> <sup>-</sup>				
1	Need of previous experience of the local workers in working with international contractors	0.38	0.00000	0.48	0.11	0.49	0.02	0.8670	0.6`160

9 After determining the distance of each alternative from FNI and FPIS the closeness coefficient of each alternative is calculated to rank the alternatives (equation 15).

The closeness coefficient  $cc_i$  represents the distances to fuzzy positive ideal solution,  $A^*$ , and the fuzzy negative ideal solution,  $A^-$  simultaneously. The closeness coefficient of each alternative is calculated as:

$$CC_i = \frac{d_i^-}{d_i^- + d_i^*}, i = 1, 2, \dots, m$$

**Table 16: Closeness coefficient**

<b>No.</b>	<b>Determinants of technology transfer (Alternative 1)</b>	<b><math>d_i^*</math></b>	<b><math>d_i^-</math></b>	<b>Cci</b>
1	Need of previous experience of the local workers in working with international contractors	0.8670	0.6160	0.4154
2	Transferor allowing the transferee to practice the new techniques on site	0.8654	0.6129	0.4146
3	Transferor training the transferee for the expected work	0.8907	0.6376	0.4172

The alternative with highest closeness coefficient represents the best alternative and is closest to the FPIS and farthest from the FNIS.

## CHAPTER FIVE

### RESULT AND DISCUSSIONS

#### 5.1 Introduction

In this section, discussion about the ranking of the determinants/factors of technology transfer from the client/client representative and employees with different discipline from the foreign contractor perspective is elaborated. And then once the determinants/factors are ranked, a frame is developed which relies on the project life cycle in the construction industry which is related with the determinants/factors for the success of transfer of new technologies that must be considered from the beginning until the end of a project construction.

##### 5.1.1 Aggregated Fuzzy Decision Matrix

**Table 17: Computed aggregated fuzzy decision matrix**

No.	Determinants/ factors of Technology Transfer (Alternatives)	Engineers (Criteria 1)	Experts (Criteria 2)	Laborer (Criteria 3)
1	Need of previous experience of the local workers in working with international contractors	(1,7.16,9)	(5,8,9)	(5,8.25,9)
2	Transferor allowing the transferee to practice the new techniques on site	(1,7.16,9)	(5,8,9)	(5,8.68,9)
3	Transferor training the transferee for the expected work	(3,8.04,9)	(5,8.67,9)	(3,6.79,9)
4	Involvement of Local Experts on Design stage of the project	(1,5.96,9)	(5,8.33,9)	(3,6.68,9)
5	Smooth communication between the Transferee and Transferor	(1,4.92,9)	(3,6,9)	(3,7.46,9)
6	Team work between the foreign and local firm	(3,7.8,9)	(5,7.33,9)	(3,6.95,9)
7	Involving constant supervision and inspection team from local company	(3,8.04,9)	(5,8.33,9)	(3,6.43,9)
8	Need of specific discipline which follows up the effectiveness of technology transfer on site	(1,6.92,9)	(5,7.33,9)	(1,4.29,9)

9	Thorough visitation of local contractors to learn and get experience	(1,7.08,9)	(5,7.67,9)	(3,7.79,9)
10	Involving local institutes to participate for the purpose of learning and do research	(3,6.28,9)	(5,8.33,9)	(1,5.57,9)
11	Need of government enforcement (regarding on design, installation and contract agreement) for the knowledge and technology transfer	(3,6.52,9)	(5,8,9)	(1,5.21,9)
12	Including a section in initial contract, which insist on for all the local parties to get involved in the project with foreign contractors	(5,7.48,9)	(7,9,9)	(3,6.79,9)
13	Hiring experienced local technicians with capacity and technical skills	(5,8.68,9)	(5,7.33,9)	(5,8.23,9)
14	Willingness of Transferor to teach and give trainings to the local employees	(3,7.8,9)	(5,7.67,9)	(5,8.27,9)
15	Need of trust within the transferee and transferor	(1,3.72,7)	(3,6,9)	(3,6.09,9)
16	Transferee commitment to learn and practice on site	(5,7.56,9)	(5,7,9)	(5,7.29,9)
17	Need of experienced expertise and engineers for the success of technology transfer	(1,5.24,9)	(3,6.33,9)	(3,6.55,9)
18	Local sub-contractors involvement on the project	(5,8.76,9)	(5,8.67,9)	(3,7.27,9)

### 5.1.2 Normalized Aggregate Fuzzy Decision Matrix

Here, the normalization method preserving the property that the ranges of normalized triangular fuzzy numbers belonging to [0,1] using  $\tilde{N} = (\tilde{n}_{ij})_{m \times n}$  equation is determined. The normalized fuzzy decision matrix is as shown on table

**Table 18: Normalized Aggregate Fuzzy Decision Matrix**

No.	Determinants/ factors of Technology Transfer (Alternatives)	Engineers (Criteria 1)	Experts (Criteria 2)	Laborer (Criteria 3)
1	Need of previous experience of the local workers in working with international contractors	(0.11,0.8,1)	(0.56,0.89,1)	(0.56,0.92,1)

2	Transferor allowing the transferee to practice the new techniques on site	(0.11,0.8,1)	(0.56,0.89,1)	(0.56,0.96,1)
3	Transferor training the transferee for the expected work	(0.33,0.89,1)	(0.56,0.96,1)	(0.33,0.75,1)
4	Involvement of Local Experts on Design stage of the project	(0.11,0.66,1)	(0.56,0.93,1)	(0.33,0.74,1)
5	Smooth communication between the Transferee and Transferor	(0.11,0.55,1)	(0.33,0.67,1)	(0.33,0.83,1)
6	Team work between the foreign and local firm	(0.33,0.87,1)	(0.56,0.81,1)	(0.33,0.77,1)
7	Involving constant supervision and inspection team from local company	(0.33,0.89,1)	(0.56,0.93,1)	(0.33,0.71,1)
8	Need of specific discipline which follows up the effectiveness of technology transfer on site	(0.11,0.77,1)	(0.56,0.81,1)	(0.11,0.48,1)
9	Thorough visitation of local contractors to learn and get experience	(0.11,0.79,1)	(0.56,0.85,1)	(0.33,0.87,1)
10	Involving local institutes to participate for the purpose of learning and do research	(0.33,0.7,1)	(0.56,0.93,1)	(0.11,0.62,1)
11	Need of government enforcement (regarding on design, installation and contract agreement) for the knowledge and technology transfer	(0.33,0.72,1)	(0.56,0.89,1)	(0.11,0.58,1)
12	Including a section in initial contract, which insist on for all the local parties to get involved in the project with foreign contractors	(0.56,0.83,1)	(0.78,1,1)	(0.33,0.75,1)
13	Hiring experienced local technicians with capacity and technical skills	(0.56,0.96,1)	(0.56,0.81,1)	(0.56,0.91,1)
14	Willingness of Transferor to teach and give trainings to the local employees	(0.33,0.87,1)	(0.56,0.85,1)	(0.56,0.92,1)
15	Need of trust within the transferee and transferor	(0.11,0.41,0.78)	(0.33,0.67,1)	(0.33,0.68,1)
16	Transferee commitment to learn and practice on site	(0.56,0.84,1)	(0.56,0.78,1)	(0.56,0.81,1)
17	Need of experienced expertise and engineers for the success of technology transfer	(0.11,0.58,1)	(0.33,0.7,1)	(0.33,0.73,1)
18	Local sub-contractors involvement on the project	(0.56,0.97,1)	(0.56,0.96,1)	(0.33,0.81,1)

### 5.1.3 Weighted Normalized Aggregate Fuzzy Decision Matrix

Here, as described in the previous chapter, the weight has been already determined by each respondent and to rate the determinants with regards to their experience and field which they believe is more important to them. There for the weighted normalized fuzzy decision matrix,  $\tilde{Nw}$  will have the same result with the normalized fuzzy decision matrix.

**Table 19: Weighted Normalized Aggregate Fuzzy Decision Matrix**

No.	Determinants/ factors of Technology Transfer (Alternatives)	Engineers (Criteria 1)	Experts (Criteria 2)	Laborer (Criteria 3)
1	Need of previous experience of the local workers in working with international contractors	(0.02,0.2,0.29)	(0.3,0.58,0.76)	(0.05,0.1,0.13)
2	Transferor allowing the transferee to practice the new techniques on site	(0.02,0.2,0.29)	(0.3,0.58,0.76)	(0.05,0.1,0.13)
3	Transferor training the transferee for the expected work	(0.07,0.22,0.29)	(0.3,0.62,0.76)	(0.03,0.08,0.13)
4	Involvement of Local Experts on Design stage of the project	(0.02,0.16,0.29)	(0.3,0.6,0.76)	(0.03,0.08,0.13)
5	Smooth communication between the Transferee and Transferor	(0.02,0.14,0.29)	(0.18,0.43,0.76)	(0.03,0.09,0.13)
6	Team work between the foreign and local firm	(0.07,0.21,0.29)	(0.3,0.53,0.76)	(0.03,0.08,0.13)
7	Involving constant supervision and inspection team from local company	(0.07,0.22,0.29)	(0.3,0.6,0.76)	(0.03,0.07,0.13)
8	Need of specific discipline which follows up the effectiveness of technology transfer on site	(0.02,0.19,0.29)	(0.3,0.53,0.76)	(0.01,0.05,0.13)
9	Thorough visitation of local contractors to learn and get experience	(0.02,0.19,0.29)	(0.3,0.55,0.76)	(0.03,0.09,0.13)

10	Involving local institutes to participate for the purpose of learning and do research	(0.07,0.17,0.29)	(0.3,0.6,0.76)	(0.01,0.06,0.13)
11	Need of government enforcement (regarding on design, installation and contract agreement) for the knowledge and technology transfer	(0.07,0.18,0.29)	(0.3,0.58,0.76)	(0.01,0.06,0.13)
12	Including a section in initial contract, which insist on for all the local parties to get involved in the project with foreign contractors	(0.12,0.21,0.29)	(0.43,0.65,0.76)	(0.03,0.08,0.13)
13	Hiring experienced local technicians with capacity and technical skills	(0.12,0.24,0.29)	(0.3,0.53,0.76)	(0.05,0.09,0.13)
14	Willingness of Transferor to teach and give trainings to the local employees	(0.07,0.21,0.29)	(0.3,0.55,0.76)	(0.05,0.1,0.13)
15	Need of trust within the transferee and transferor	(0.02,0.1,0.23)	(0.18,0.43,0.76)	(0.03,0.07,0.13)
16	Transferee commitment to learn and practice on site	(0.12,0.21,0.29)	(0.3,0.5,0.76)	(0.05,0.08,0.13)
17	Need of experienced expertise and engineers for the success of technology transfer	(0.02,0.14,0.29)	(0.18,0.46,0.76)	(0.03,0.08,0.13)
18	Local sub-contractors involvement on the project	(0.12,0.24,0.29)	(0.3,0.62,0.76)	(0.03,0.08,0.13)

#### 5.1.4 Fuzzy Positive Ideal Solution (FPIS) & Fuzzy Negative Ideal Solution (FNIS)

The Fuzzy Positive Ideal Solution (FPIS) and the Fuzzy Negative Ideal Solution (FNIS) in TOPSIS approach is calculated so as to determine the distance of the weighted normalized result. Hence the FPIS (  $A^*$  ) & FNIS (  $A^-$  ) for each alternative is calculated and the result shows as shown on the table below.

**Table 20: Fuzzy Positive Ideal Solution (FPIS) & Fuzzy Negative Ideal Solution (FNIS)**

No.	Determinants/ factors of Technology Transfer (Alternatives)	$A^*$	$A^-$
1	Need of previous experience of the local workers in working with international contractors	(0.3,0.58,0.76)	(0.02,0.1,0.13)
2	Transferor allowing the transferee to practice the new techniques on site	(0.3,0.58,0.76)	(0.02,0.1,0.13)

3	Transferor training the transferee for the expected work	(0.3,0.62,0.76)	(0.03,0.08,0.13)
4	Involvement of Local Experts on Design stage of the project	(0.3,0.6,0.76)	(0.02,0.08,0.13)
5	Smooth communication between the Transferee and Transferor	(0.18,0.43,0.76)	(0.02,0.09,0.13)
6	Team work between the foreign and local firm	(0.07,0.53,0.76)	(0.03,0.08,0.13)
7	Involving constant supervision and inspection team from local company	(0.3,0.6,0.76)	(0.03,0.07,0.13)
8	Need of specific discipline which follows up the effectiveness of technology transfer on site	(0.3,0.53,0.76)	(0.01,0.05,0.13)
9	Thorough visitation of local contractors to learn and get experience	(0.03,0.55,0.76)	(0.02,0.09,0.13)
10	Involving local institutes to participate for the purpose of learning and do research	(0.3,0.6,0.76)	(0.01,0.06,0.13)
11	Need of government enforcement (regarding on design, installation and contract agreement) for the knowledge and technology transfer	(0.3,0.58,0.76)	(0.01,0.06,0.13)
12	Including a section in initial contract, which insist on for all the local parties to get involved in the project with foreign contractors	(0.43,0.65,0.76)	(0.03,0.08,0.13)
13	Hiring experienced local technicians with capacity and technical skills	(0.3,0.53,0.76)	(0.05,0.09,0.13)
14	Willingness of Transferor to teach and give trainings to the local employees	(0.3,0.55,0.76)	(0.05,0.21,0.29)
15	Need of trust within the transferee and transferor	(0.18,0.43,0.76)	(0.02,0.07,0.13)
16	Transferee commitment to learn and practice on site	(0.3,0.5,0.76)	(0.05,0.08,0.13)
17	Need of experienced expertise and engineers for the success of technology transfer	(0.18,0.46,0.76)	(0.02,0.08,0.13)
18	Local sub-contractors involvement on the project	(0.3,0.62,0.76)	(0.03,0.08,0.13)

### 5.1.5 Distance of each alternative from FPIS & (FNIS)

Once the FPIS and FNIS is determined as shown above on the table20, the distance of each alternative from FPIS and FNIS is determined so as to identify the closeness coefficient  $cc_i$ .

The optimal solution is later on determined by the closeness coefficient. Hence the calculated distance is shown in table 21

$$d_i^* = \sum_{j=1}^n d_v(\tilde{v}_{ij}, \tilde{v}_j^*), i = 1, 2, \dots, m, \text{ where } d_v = \sqrt{\frac{1}{3} [(a - a')^2 + (b - b')^2 + (c - c')^2]}$$

$$d_i^- = \sum_{j=1}^n d_v(\tilde{v}_{ij}, \tilde{v}_j^-), i = 1, 2, \dots, m$$

Table 21: Distance of each alternative from FPIS & (FNIS)

No.	Determinants/ factors of Technology Transfer (Alternatives)	dv*			dv-			d <sub>i</sub> *	d <sub>i</sub> <sup>-</sup>
		Engineers (Criteria 1)	Experts (Criteria 2)	Laborers (Criteria 3)	Engineers (Criteria 1)	Experts (Criteria 2)	Laborers (Criteria 3)		
1	Need of previous experience of the local workers in working with international contractors	0.38	0.00000	0.48	0.11	0.49	0.02	0.8670	0.6160
2	Transferor allowing the transferee to practice the new techniques on site	0.38	0.00	0.48	0.11	0.49	0.02	0.8654	0.6129
3	Transferor training the transferee for the expected work	0.38	0.00	0.51	0.13	0.51	0.00	0.8907	0.6376
4	Involvement of Local Experts on Design stage of the project	0.40	0.00	0.50	0.11	0.50	0.00	0.90	0.61
5	Smooth communication between the Transferee and Transferor	0.33	0.00	0.43	0.10	0.43	0.00	0.76	0.53
6	Team work between the foreign and local firm	0.33	0.14	0.45	0.13	0.48	0.00	0.91	0.60
7	Involving constant supervision and inspection team from local company	0.37	0.00	0.50	0.13	0.50	0.00	0.88	0.63
8	Need of specific discipline which follows up the effectiveness of technology transfer on site	0.37	0.00	0.49	0.13	0.49	0.00	0.86	0.62

9	Thorough visitation of local contractors to learn and get experience	0.34	0.16	0.45	0.11	0.48	0.00	0.95	0.60
10	Involving local institutes to participate for the purpose of learning and do research	0.39	0.00	0.51	0.12	0.51	0.00	0.90	0.63
11	Need of government enforcement (regarding on design, installation and contract agreement) for the knowledge and technology transfer	0.38	0.00	0.50	0.12	0.50	0.00	0.88	0.63
12	Including a section in initial contract, which insist on for all the local parties to get involved in the project with foreign contractors	0.41	0.00	0.54	0.13	0.54	0.00	0.96	0.67
13	Hiring experienced local technicians with capacity and technical skills	0.34	0.00	0.47	0.13	0.47	0.00	0.80	0.60
14	Willingness of Transferor to teach and give trainings to the local employees	0.36	0.00	0.47	0.01	0.36	0.12	0.84	0.49
15	Need of trust within the transferee and transferor	0.37	0.00	0.43	0.06	0.43	0.00	0.80	0.50
16	Transferee commitment to learn and practice on site	0.34	0.00	0.46	0.13	0.46	0.00	0.80	0.59
17	Need of experienced expertise and engineers for the success of technology transfer	0.34	0.00	0.44	0.10	0.44	0.00	0.77	0.55
18	Local sub-contractors involvement on the project	0.37	0.00	0.51	0.14	0.51	0.00	0.87	0.65

As shown on table 21, the distance of each alternative from FPIS and FNIS are very close to each other, but still have different result. Once the distance of each determinants from the positive ideal solution and the negative ideal solution are identified, the closeness coefficient is determined.

### 5.1.6 Closeness coefficient

The result of closeness coefficient,  $cc_i$  represents the distance to positive ideal solution  $A^*$  and the negative ideal solution,  $A^-$ . The alternative with highest closeness coefficient represents the best alternative and is ranked as per their result. The closeness coefficient,  $cc_i$  and the rank of each alternative is shown in table22.

$$cc_i = \frac{d_i^-}{d_i^- + d_i^*}$$

**Table 22: closeness coefficient & Ranked result**

No.	Determinants/ factors of Technology Transfer (Alternatives)	$d_i^*$	$d_i^-$	Cci	Rank
1	Need of previous experience of the local workers in working with international contractors	0.8670	0.6160	0.4154	7
2	Transferor allowing the transferee to practice the new techniques on site	0.8654	0.6129	0.4146	9
3	Transferor training the transferee for the expected work	0.8907	0.6376	0.4172	5
4	Involvement of Local Experts on Design stage of the project	0.90	0.61	0.40	14
5	Smooth communication between the Transferee and Transferor	0.76	0.53	0.41	12
6	Team work between the foreign and local firm	0.91	0.60	0.40	15
7	Involving constant supervision and inspection team from local company	0.88	0.63	0.42	4

8	Need of specific discipline which follows up the effectiveness of technology transfer on site	0.86	0.62	0.42	6
9	Thorough visitation of local contractors to learn and get experience	0.95	0.60	0.39	16
10	Involving local institutes to participate for the purpose of learning and do research	0.90	0.63	0.41	13
11	Need of government enforcement (regarding on design, installation and contract agreement) for the knowledge and technology transfer	0.88	0.63	0.41	8
12	Including a section in initial contract, which insist on for all the local parties to get involved in the project with foreign contractors	0.96	0.67	0.41	10
13	Hiring experienced local technicians with capacity and technical skills	0.80	0.60	0.43	1
14	Willingness of Transferor to teach and give trainings to the local employees	0.84	0.49	0.37	18
15	Need of trust within the transferee and transferor	0.80	0.50	0.38	17
16	Transferee commitment to learn and practice on site	0.80	0.59	0.42	3
17	Need of experienced expertise and engineers for the success of technology transfer	0.77	0.55	0.41	11
18	Local sub-contractors involvement on the project	0.87	0.65	0.43	2

Once the closeness of coefficient is determined, then one with the highest number which is the best alternative is ranked as number one. Hence, priority to hiring experienced local technicians with capacity and technical skills is given in order to have a successful technology transfer in the Highrise building construction from transferor to transferee. This means that only hiring local workers on the site is not important as it seems. Rather hiring workers with experience to accept the new techniques and knowledges from the transferor and practice it easily on the job, seems to be the number one priority determinant for technology transfer to develop. Hence as per their rank

shown on table 22, the importance of each determinant must be prioritized and considered on any given high-rise building project for technology transfer to exist and apply.

## 5.2 Discussion

Knowing, understanding and determining the factors for the success of technology transfer in construction industry is the first step for the achievement of transformation and re-engineering the common traditional construction work. In this study 18 determinants were to be identified and ranked for CBEHQ project local workers from both the local company and foreign contractors. In the study Fuzzy TOPSIS principle has been used to rank the determinants as their importance to the respondents which were classified in three categories (experts, engineers and laborers). The identified determinants were ranked as per every respondent experience on the given project.

As per their prioritized rank, the importance of the determinants/ factors are more explained and discussed in detail in the following table 23.

**Table 23 Importance of factors/determinants of technology transfer**

No.	Determinants/ factors of Technology Transfer (Alternatives)	The need of each factors/determinants to practice on a given project
1	Hiring experienced local technicians with capacity and technical skills	This is very significant aspect for the success of technology transfer and adaptation. Hiring experienced local technicians is important because the techniques, skills, and machineries operated by the transferors are more advanced and needs experienced technicians with the capacity and technical skill knowledge. This will make the learning and teaching/training relationship between the transferee and transferor easier & not exhausting. Once the technicians get the experience from this kind of project, they will advance it more. Hence, they are able to adopt, practice and work on new projects, and they will be another means for transferring the new technologies to the local workers. This is one factor that affects the success of technology transfer.
2	Local sub-contractor involvement on the project	There are many channels for the technology transfer to be successful, to name some FDI, licensing technology, joint venture and international trade. However, if an international company, as a transferor, works on local project works, then for the advantage of growth, the host (transferee) must have a means to work with transferor together on the project.

		Besides hiring local technical workers on the project, involvement of local sub-contractor is very necessary. This way the firm by itself (local sub-contractor) is able to practice on new techniques, management works, safety works and technical works. The sub-contractor is able to develop their capacity as a company involving workers under them. Once the local subcontractor learns and adopt the new technologies from the transferors, they will be able to practice and work on new construction project as a contractor through time.
3	Transferee commitment to learn and practice on site	So, if there is a means of involving local workers (transferee) in projects where there are international companies working on local developed countries, in this case, Ethiopia, then we must make sure that the transferee is committed to learn and advance their knowledge and techniques of works. The transferee has the role to play on this part very wisely and smartly since working on this kind of projects will develop their knowledge as a profession for their own growth and for the country as well.
4	Involving constant supervision and inspection team from local company	On the work of construction project, it is known that supervision throughout the project life, has a big place for the success of completion of the project as per planned. In the involvement of international company working on local country as a contractor, supervision can be handled by local employees (as a transferee) who are experienced and experts on the field. This is another factor for the success of technology transfer, where the local supervisors learn more and develop their knowledge through the inspection and control of the work on the project. This way, new techniques, machineries, tools can be introduced from the transferor to transferee. The transferee can advise, suggest and use the knowledge & techniques they grasped and forward it on other projects.
5	Transferor training the transferee for the expected work	Training before working on the job is very important to know how it works and get the knowledge. If it is possible, the transferor must train the local employees by willing for them to practice it on the project., if not there has to be a means of agreement between the client and the contractor (transferor) for them to give a training for the transferee.
6	Need of specific discipline which follows up the effectiveness of technology transfer on site	Once there is an agreement for the practice of technology transfer and expected local workers are hired and starts working with the transferor, how can we make sure that if there is a technology transfer as per planned, if the transferors are really giving training or not, and if the transferors are practicing it. If learning and practicing new technology for the development construction is thought to

		be helpful for one country's construction industry development, then we must use the advantage and act on it. Hence as there are disciplines for inspecting the work in the project, quality & safety practice, there needs to be a discipline which follows up and inspects the effectiveness of technology transfer between the transferee and transferor.
7	Need of previous experience of the local workers in working with international contractors	High rise buildings are being construction in Ethiopia now a days. This construction has been handled by foreign contractors, who have the capacity to construct big projects and are internationally well known. Hence, local workers who have been involved in working with international contractors, not as big, but relatively with good experience, will have the capacity to grasp and practice on the new technology & knowledge easily, which makes the technology transfer easy and successful.
8	Need of government enforcement (regarding on design, installation and contract agreement) for the knowledge and technology transfer	It is known that there are different means of contract agreement of a project within local owners & foreign contractors. To mention some: JV, DB, Traditional type. As a government of one country, their involvement in the need of Technology transfer in Ethiopia is very important due by enforcing the foreign contractor to involve local workers. This is another means for the contractor and the client to have an agreement bounded by law which states the need of technology transfer and practicing it on the host country.
9	Transferor allowing the transferee to practice the new techniques on site	Not only training the transferee but also involving the workers on the actual work which revolves around new management system, design, quality safety practice, techniques, tools & machinery to have a practical experience which will be forwarded from the transferor.
10	Including a section in initial contract, which insist on for all the local parties to get involved in the project with foreign contractors	Having a written contract between the contractor (Transferor) and the client (Transferee) which states the need for the transferor to teach, train transferee and practice with them on the actual work on site is important. this is also another factor which drives for the technology transfer to exist. However, not only stating it on the agreement but also really practicing the technology transfer must be monitored and checked.
11	Need of experienced expertise and engineers for the success of technology transfer	Local experienced experts and engineers working on designs, management works, installation works, quality and safety works on site with the transferor is also another important factor. This is for the smooth and easy technology transfer.
12	Smooth communication between the Transferee and Transferor	For the transferors and transferee work together and have a smooth and easy trend of work throughout the project work, there needs to be a good communication between them. It is

		very necessary from the transferee to know what they are working on and what they are practicing on the site. This can be done by an involvement of translator or means of letters which both parties can understand.
13	Involving local institutes to participate for the purpose of learning and do research	Though it is important to get trained & practice on the site work for the success of technology transfer, knowledge must be transferred through education as well. This can be done by involving internship students to practice on site and doing researches. This way there can be a means to know what new technologies are being used on the project.
14	Involvement of Local Experts on Design stage of the project	This can be difficult because of the agreement between the local owner and the contractor of the project. In some cases, there are times where the agreement between them can be DB (Design & Build), which makes it difficult for the locals to get involve in design stage. However, from the beginning of the agreement, if there is a means for the local designers to work with the transferee, it will be a good means of knowledge transfer.
15	Team work between the foreign and local firm	Team work of the transferee and transferor is also another means for the technology transfer to be successful. However, in some cases, like project management system, the contractors tend to work on their own system. Hence, it might not be easy to adopt their management system.
16	Thorough visitation of local contractors to learn and get experience	The local contractors visiting site where there is a new technology practice, will help them to develop their way of thinking on project works, such as on using new machineries, simple tools, utilities and take that as a lesson to practice on their work.
17	Need of trust within the transferee and transferor	Working in unfamiliar place is often hard which makes it hard for trust (to share ideas, goals, fairness in sharing different skills, sharing of a set of philosophies that the company finds acceptable) to exist between the transferor and transferee, and can be hard for technology transfer to exist. Hence, there has to be a trust developed between the transferor and transferee while working together.
18	Willingness of Transferor to teach and give trainings to the local employees	Of course, through agreement between the local host and the foreign contractor, it can be insisted to give training and work together which is a very important means for the technology to be transferred. However, while working on the project, it is easier for the transferor to be willing to teach and train the local workers, for smooth relationship.

### **5.2.1 Transferee perspective for the barrier of technology transfer**

The local workers (Transferee) were asked to rate the level of the foreign contractor if they essentially practice the technology transfer on site and identify the gap by rating the questions (ANNEX). The response was negative and described as follows:

- The transferor not willing to teach and give trainings,
- Communication problem within the transferee and transferor,
- No trust between the transferee and transferor
- No discipline involved to check the existence of the technology transfer from transferor to transferor
- Even though there is an agreement between the local client and the foreign contractor for the practice of technology transfer, it has not actually been practiced on site.

### **5.2.2 Transferor perspective of the local workers on site**

To understand the willingness of the local workers (transferee) to learn and practice the new technology that is being practiced by the foreign contractors (transferor) on the site, the transferee was able to rate their willingness and level of understanding (ANNEX). The result shows that the transferee intent to learn more and develop their knowledge and skill by receiving training and practicing on the site with the transferor. However, to make sure if the transferee is willing to get involve with the transferor and shows an effort to learn more, the transferor was also able to rate the willingness of the transferee to learn, train, and practice and result shows positive response with relate to the transferee response.

### **5.2.3 Transferee perspective on the determinants/factors for the success of technology transfer**

After understanding the existence of technology transfer gap which exists in the given study case project, a study on the factors for the success of technology transfer has been done through literature review. Then to prioritize the importance of the determinants or factors for the success of technology transfer, the transferee (client/client representative and local employees from the

foreign contractor) were able to rate according to their actual work on site and their need to fill the gap on the technology transfer that exists on the site.

Even though there is an agreement between the foreign contractor, transferor (CSCEC) and the client (CBEHQ) project, on Article 5.3.1, which states for the practice of technology transfer on the given project, the study shows a big gap on technology transfer process. Due to the respondents replies (from the local employee side and from the contractor side), gaps were identified as shown in table 24.

**Table 24: Identified Problems in Technology transfer between the transferee (CSCEC) and transferor (local employees)**

No.	Determinants/ factors of Technology Transfer (Alternatives)	The need of each factors/determinants to practice it on a given project	Gaps found in practicing Technology transfer on the case study (CBE HQ) project
1	Hiring experienced local technicians with capacity and technical skills	This is very significant aspect for the success of technology transfer and adaptation. Hiring experienced local technicians is important because the techniques, skills, and machineries operated by the transferors are more advanced and needs experienced technicians with the capacity and technical skill knowledge. This will make the learning and teaching/training relationship between the transferee and transferor easier & not exhausting. Once the technicians get the experience from this kind of project, they will advance it more. Hence, they will be able to adopt, practice and work on new projects, and they will be another means for transferring the new technologies to the local workers. This is one factor that affects the success of technology transfer.	<ul style="list-style-type: none"> <li>• As per the transferor’s response, the hired local employees, especially the local laborers are not experienced, which makes it for the transferor to teach and train them as well.</li> <li>• However, this is due to the fact that the transferor (foreign contractor) hired only helper laborers, which means they will not be practicing on the technical work but only helping the foreign technicians with minor works. Hence, the local workers will not be able to develop their technical skill.</li> </ul>
2	Local sub-contractor involvement on the project	There are many channels for the technology transfer to be successful, to name some FDI, licensing technology, joint venture and international trade. However, if an international company, as a transferor, works on local project works, then for the advantage of growth, the host (transferee) must have a means to work with transferor together on the project. Besides hiring local technical workers on the project, involvement of local sub-contractor is very necessary. This way the firm by itself (local sub-	<ul style="list-style-type: none"> <li>• There is no local sub-contractor which works on the project.</li> <li>• All the construction has been done through the contractor. This is due to the agreement between the client and the contractor.</li> <li>• Hence, as big as the project is for Ethiopia (No. one in Ethiopia and No. 3 in Africa, no local sub-contractor has been practiced and</li> </ul>

		contractor) will be able to practice on new techniques, management works, safety works and technical works. The sub-contractor will be able to develop their capacity as a company involving workers under them. Once the local subcontractor learns and adopt the new technologies from the transferors, they will be able to practice and work on new construction project as a contractor through time.	no important technology transfer has been introduced.
3	Transferee commitment to learn and practice on site	So, if there is a means of involving local workers (transferee) in projects where there are international companies working on local developed countries, in this case, Ethiopia, then we must make sure that the transferee is committed to learn and advance their knowledge and techniques of works. The transferee has the role to play on this part very wisely and smartly since working on this kind of projects will develop their knowledge as a profession for their own growth and for the country as well.	-
4	Involving constant supervision and inspection team from local company	On the work of construction project, it is known that supervision throughout the project life, has a big place for the success of completion of the project as per planned. In the involvement of international company working on local country as a contractor, supervision can be handled by local employees (as a transferee) who are experienced and experts on the field. This is another factor for the success of technology transfer, where the local supervisors learn more and develop their knowledge through the inspection and control of the work on the project. This way, new techniques, machineries, tools can	<ul style="list-style-type: none"> <li>• Local client representative works on supervision and inspection work.</li> <li>• Of course, there has been some means of knowledge and techniques that has been transferred from the transferor, through constant inspection on the site, but on the design level, only review is being handled by the client representative.</li> </ul>

		be introduced from the transferor to transferee. The transferee can advise, suggest and use the knowledge & techniques they grasped and forward it on other projects.	<ul style="list-style-type: none"> <li>Hence, there is only a partial design knowledge transfer from the transferor to the local design team.</li> </ul>
5	Transferor training the transferee for the expected work	Training before working on the job is very important to know how it works and get the knowledge. If it is possible, the transferor must train the local employees by willing for them to practice it on the project., if not there has to be a means of agreement between the client and the contractor (transferor) for them to give a training for the transferee.	<ul style="list-style-type: none"> <li>As per the local employee responses on the questionnaire for identifying the gap for the technology transfer, there has not been any training given on the work, since the foreign contractor already hired foreign technicians and workers.</li> <li>The laborers are only giving a hand for the workers with small works.</li> </ul>
6	Need of specific discipline which follows up the effectiveness of technology transfer on site	Once there is an agreement for the practice of technology transfer and expected local workers are hired and starts working with the transferor, how can we make sure that if there is a technology transfer as per planned, if the transferors are really giving training or not, and if the transferors are practicing it. If learning and practicing new technology for the development construction is thought to be helpful for one country's construction industry development, then we must use the advantage and act on it. Hence as there are disciplines for inspecting the work in the project, quality & safety practice, there needs to be a discipline which follows up and inspects the effectiveness of technology transfer between the transferee and transferor.	<ul style="list-style-type: none"> <li>No one follows up the technology transfer process even though there is agreement between the client and the contractor.</li> </ul>

7	Need of previous experience of the local workers in working with international contractors	High rise buildings are being construction in Ethiopia now a days. This construction has been handled by foreign contractors, who have the capacity to construct big projects and are internationally well known. Hence, local workers who have been involved in working with international contractors, not as big, but relatively with good experience, will have the capacity to grasp and practice on the new technology & knowledge easily, which makes the technology transfer easy and successful.	-
8	Need of government enforcement (regarding on design, installation and contract agreement) for the knowledge and technology transfer	It is known that there are different means of contract agreement of a project within local owners & foreign contractors. To mention some: JV, DB, Traditional type. As a government of one country, their involvement in the need of Technology transfer in Ethiopia is very important due by enforcing the foreign contractor to involve local workers. This is another means for the contractor and the client to have an agreement bounded by law which states the need of technology transfer and practicing it on the host country.	-
9	Transferor allowing the transferee to practice the new techniques on site	Not only training the transferee but also involving the workers on the actual work which revolves around new management system, design, quality safety practice, techniques, tools & machinery to have a practical experience which will be forwarded from the transferor.	<ul style="list-style-type: none"> <li>• As per the local employee responses, there has not been any training given on the work, hence, they are not practicing on the new techniques as they are supposed to (they are not working on the production &amp; installation works on site).</li> </ul>

10	Including a section in initial contract, which insist on for all the local parties to get involved in the project with foreign contractors	Having a written contract between the contractor (Transferor) and the client (Transferee) which states the need for the transferor to teach, train transferee and practice with them on the actual work on site is important. this is also another factor which drives for the technology transfer to exist. However, not only stating it on the agreement but also really practicing the technology transfer must be monitored and checked.	<ul style="list-style-type: none"> <li>• There is an article on the agreement between the contractor and the client which states to train transfer and exercise technology transfer, however the respondents replied that it has not been practiced well as big as the project is.</li> </ul>
11	Need of experienced expertise and engineers for the success of technology transfer	Local experienced experts and engineers working on designs, management works, installation works, quality and safety works on site with the transferor is also another important factor. This is for the smooth and easy technology transfer.	<ul style="list-style-type: none"> <li>• The local employees, as per their profession background states, they have the expected experience more or less.</li> </ul>
12	Smooth communication between the Transferee and Transferor	For the transferors and transferee work together and have a smooth and easy trend of work throughout the project work, there needs to be a good communication between them. It is very necessary from the transferee to know what they are working on and what they are practicing on the site. This can be done by an involvement of translator or means of letters which both parties can understand.	<ul style="list-style-type: none"> <li>• Experts and engineers responded that there is not that much problem communicating with the transferor party.</li> <li>• The laborers, however have a problem communicating with the transferee, since they can not speak with international language, hence it is very hard to understand with each other.</li> </ul>
13	Involving local institutes to participate for the purpose of learning and do research	Though it is important to get trained & practice on the site work for the success of technology transfer, knowledge must be transferred through education as well. This can be done by involving internship students to practice on site and doing researches. This way there can be a means to	<ul style="list-style-type: none"> <li>• Institutes, from different universities come for an internship for four months. While they do that, they work on site as well as study &amp; learn the design work in the office on the client's side.</li> </ul>

		know what new technologies are being used on the project.	<ul style="list-style-type: none"> <li>• The employees give them a brief description on what is being done on the site and then take them for site inspection.</li> <li>• However, they are limited with only the knowledge they get from the client’s representative side.</li> </ul>
14	Involvement of Local Experts on Design stage of the project	This can be difficult because of the agreement between the local owner and the contractor of the project. In some cases, there are times where the agreement between them can be DB (Design & Build), which makes it difficult for the locals to get involve in design stage. However, from the beginning of the agreement, if there is a means for the local designers to work with the transferee, it will be a good means of knowledge transfer.	<ul style="list-style-type: none"> <li>• Since the agreement between the contractor and the client is limited with DB, the client representative is limited to work on the design review.</li> <li>• Even though there is a knowledge transfer while doing the design review, it is not as much as getting involved through out the design work of the project.</li> </ul>
15	Team work between the foreign and local employees	Team work of the transferee and transferor is also another means for the technology transfer to be successful. However, in some cases, like project management system, the contractors tend to work on their own system. Hence, it might not be easy to adopt their management system.	<ul style="list-style-type: none"> <li>• Since the transferor do not let the transferee to practice on the work, there is no team work between the transferee and transferor.</li> </ul>
16	Thorough visitation of local contractors to learn and get experience	The local contractors visiting site where there is a new technology practice, will help them to develop their way of thinking on project works, such as on using new machineries, simple tools, utilities and take that as a lesson to practice on their work.	-
17	Need of trust within the transferee and transferor	Working in unfamiliar place is often hard which makes it hard for trust (to share ideas, goals, fairness in sharing different skills, sharing of a set	<ul style="list-style-type: none"> <li>• The transferee (experts, engineers &amp; laborers) responded that the transferor do not share any ideas,</li> </ul>

		of philosophies that the company finds acceptable) to exist between the transferor and transferee, and can be hard for technology transfer to exist. Hence, there has to be a trust developed between the transferor and transferee while working together.	and that their goal is just to finish their work and leave.
18	Willingness of Transferor to teach and give trainings to the local employees	Of course, through agreement between the local host and the foreign contractor, it can be insisted to give training and work together which is a very important means for the technology to be transferred. However, while working on the project, it is easier for the transferor to be willing to teach and train the local workers, for smooth relationship.	<ul style="list-style-type: none"> <li>All the local workers responded that the transferor is not willing to give trainings and teach the workers, even though the agreement implies they have to.</li> </ul>

The identified gaps which are mentioned in the table are the main barriers for the technology transfer to happen on the given case project. This project, CBEHQ project is the first high rise building which costs 6 billion Ethiopian birr, and is ranked number one in Ethiopia and number 3 from Africa. The project is constructed by the most well-known international contractor, china state construction engineering cooperation (CSCEC) who works on Highrise buildings and big projects worldwide. They are the largest construction company in the world by revenue and the 14th largest general contractor in terms of overseas sales, as of 2016 (ENR, 2016). Hence, this is a good opportunity for the local workers, to learn, train and practice on the project. However as discussed above, the technology transfer is not being considered seriously. This study's first work is to determine the factors/determinants for technology transfer and then, and ranking their importance as per the workers opinion of the project. Not only ranking the importance of technology transfer, a survey has been taken to identify if there was a technology transfer in the project, and if there is where the gap is. These gaps are identified and then with the help of the ranked determinants of Technology transfer, a framework is developed. This frame work is developed by implementing the factors on the given project life cycle. From the respondent experience and answers collected, the factors are implemented on the project considering the project life cycle. Whenever there is a project to construct, there are 4 important cycle to consider. This are project initiation phase, project planning phase, project implementation & monitoring phase and the close out phase. More discussion on the relation with the factors of technology transfer and their implementation on the project life cycle is presented on the next chapter.

## CHAPTER SIX

### FRAMEWORK OF DETERMINANTS OF TT TO BE IMPLEMENTED IN PROJECT LIFE CYCLE

In the process of project life cycle, for the case of a given project where there is an involvement of developed countries to handle the construction in developing country, one must consider the need of technology transfer. It is known that in Ethiopia, high rise buildings are being constructed by involving international contractors, which have the capacity to build mega projects. Hence, after identifying the main determinants of factors for the success of technology transfer, it can be related throughout a project life cycle of a given project.

Every project has a beginning stage, middle stage and end stage. This stage are a path which must be considered as a standard when handling a project (Lester, 2014). This path includes four phases which is stated below:

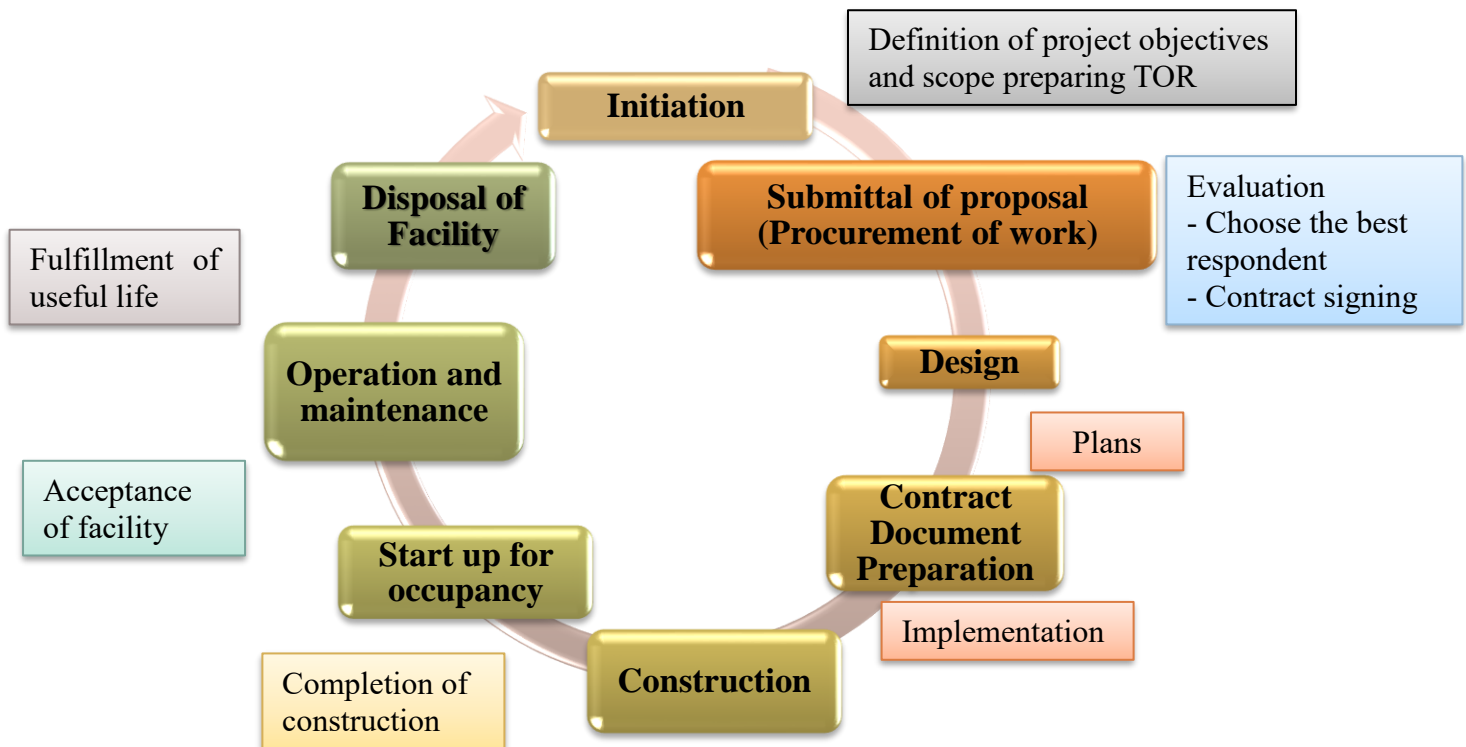
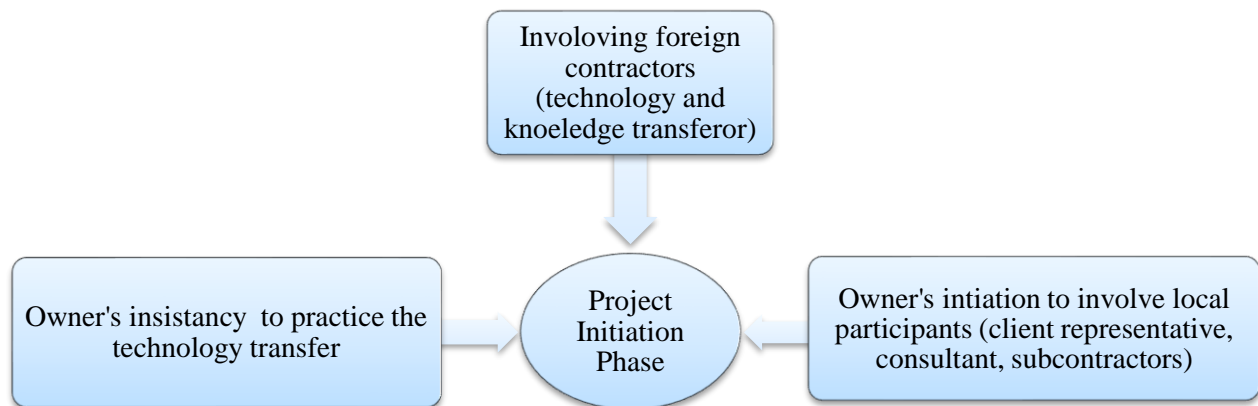


Figure 7: Life cycle of a construction project

Within the described 4 phases of project life cycle in a given project, factors which leads to for the success of technology transfer can be implemented in each stage. Since this study relies on the process of technology transfer from transferor to transferee, a frame work is proposed to implement the determined factors on the project life cycle.

**Initiating phase:** this is a phase where a project objective is identified, response to the need is documented in a business case with recommended solution option and feasibility issues & justification are addressed (Leonore van den Ende, 2014).



**Figure 8: Project Initiation phase**

**Planning phase:** in this phase, processes required to establish the scope and of the project is defined. Project team is identified, project team task, activities and resource requirements, required skills, reporting relationships, quality plan and assurance, project budget and schedule will be identified through the human resource plan, and creating a staffing management plan. In this stage the project stakeholders are identified and can establish a communication plan describing the information needed and the delivery method to be used (Albert, 2007).

So, in this project planning phase, how can we relate the technology transfer process where there is an involvement of international contractor. Once the owner of the given project has initiated the need for technology transfer while doing the project, the next step is involving the right parties which can actually do the work and check the work. This include:

- Involvement of Local contractors & workers: the client must be involved during the pre-construction phase in the project planning. They can insist on the involvement of the local sub-contractors and workers. Hence in this stage when the planning is processed, the responsible party must include an article which states that the foreign contractor (Transferor) to involve sub-contractors & local workers on their behalf. However, the local workers (expertise, engineers, technicians & laborers) must have the capacity to work with the foreign contractor (transferor), to accept the new technology and knowledge to be transferred. The commitment level of the local workers must be addressed as well. In this process the human resource will play a big role to hire capable local workers of both the foreign and local contractors. The other agreement between the client and the foreign contractor is to include a training and practice program. This agreement must be considered when the client is private, public or public private relation. Even though there are different construction project which revolves around technology transfer, it still has not been well practiced. Take the chosen case study, there are of course different means for technology transfer, however it is not well practiced and no one actually monitors and checks if the technology transfer is practiced. Hence as big as this project is for development of construction industry in Ethiopia, the success of technology transfer between the transferor and transferee is not well practiced and adopted. This study proposes that from the client's side, sub-contractor (local) side or from the consulting side, there must be a discipline which inspects and follows up the implementation of technology transfer on a given project.
- Involvement of an institute: the need of institute plays a big role in technology transfer as well. This means involving students on the actual work of the project for a given time, to study and do institutional research. This is another way of taking a knowledge from transferor and developing one's knowledge about construction project and transfer it to upcoming students through documentation and publishes.
- Involvement of public procurement agency where there is a foreign contractor working on the local project must be considered, since it is important for the use of one country's need to use the opportunity of the technology transfer to practice and adopt it.

In the project planning phase, different tasks are assigned for the responsible party. Hence, when there is a need for technology transfer, there is a need for the workers to be trained, which indirectly affects the budget of the work. The training budget must be also considered, since it plays a big role in TT and adaptation.

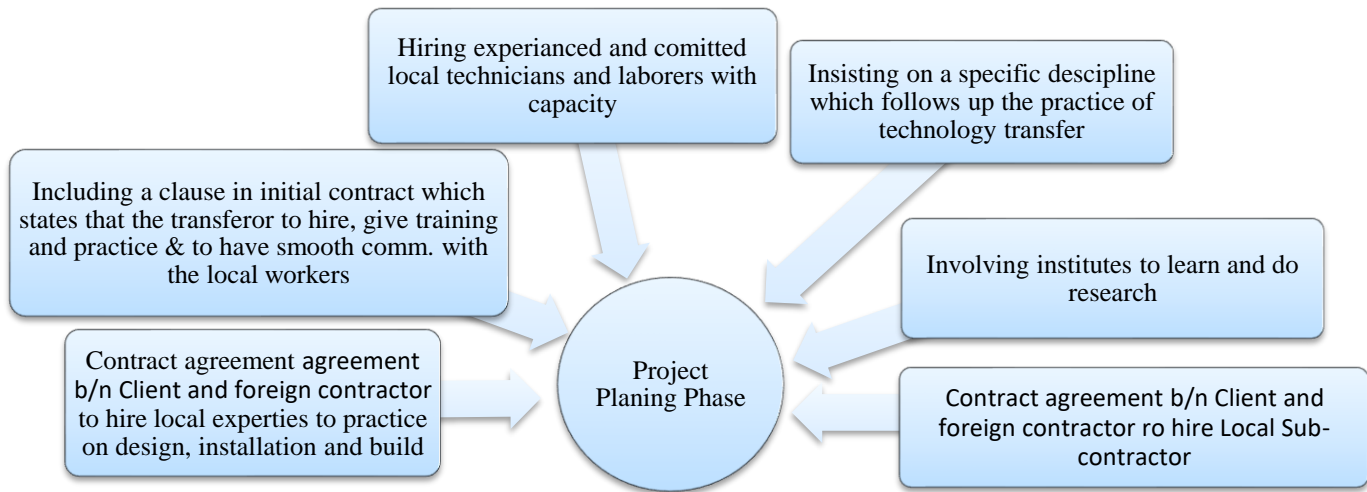


Figure 9: Project Planning phase

**Implementing and monitoring phase:** the project plan is put into motion and performance to complete the work is checked. In this process the defined actions on the project management plan is monitored by checking the progress throughout the project life and maintain the progress as per the plan. If the progress is to be found to have some changes from the plan, corrective action is needed by the designated party (Lester E. i., 2014) . Once all the deliverables have been produced and the client has accepted the final solution, the project is ready for closure.

In this phase once the need of technology transfer is proposed and included in the work plan, it is implemented throughout the project. However, it must be monitored if there is actually a technology transfer, and is being practiced. This is done by checking if there is a team work within the foreign contractors and local workers & there is a communication problem or not, if the local workers have been given trainings by the foreign contractor (technology transferor) related with their field of work, if the local workers are practicing on the given job, if the transferor is really willing to teach local workers, and if the transferee is willing to practice, if new tools and techniques has been introduced to the transferee and are using it on the project. Since the mentioned task is vast and needs constant monitoring, the assigned responsible party (can be from consulting office, sub-contractor office, or from client representative) must follow up the

performance of Technology transfer practice. This process is the same as monitoring the project work on site with regard to construction works and safety related works which is handled by constant supervision and inspection by the responsible party (can be consulting office, or client representative). The need of monitoring of the implemented work at every stage is to asses if the work is done as per the plan. If it is found to be otherwise, then the problem has to be corrected at early stage.

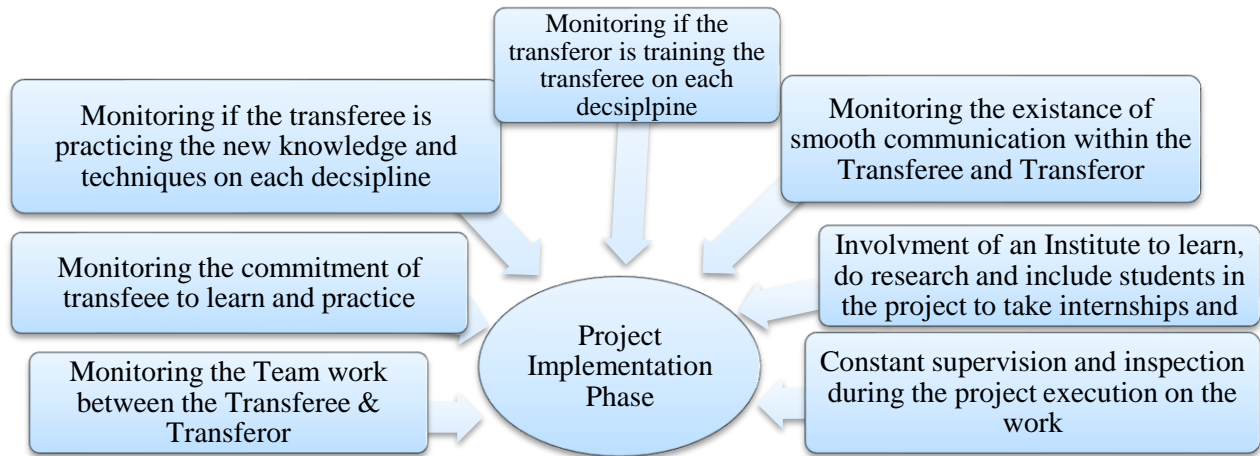


Figure 10: Project Implementation phase

**Closing phase:** in the final phase, the emphasis is to handover the project documentation to the business, terminating supplier contracts, releasing project resources, and communicating the closure of the project to all stakeholders. However, in this stage conducting lessons-learned studies to examine what went well and what went wrong is checked. The insight of experience is transferred back to the project organization, which will help future project teams. Not only that after the project has been handed over and training has been given well as per the plan, maintenance work & new machineries that are installed in the project will be operated by the trained man power. This another means of adopting the new technology that has been transferred. At this stage, there are two types of resources which are useful after the project has been handed over. These are man power resource (knowledge and skill based) and techniques/machineries/tools which are introduced from the foreign contractors and can be adopted by the local expertise, engineers and laborers. If the work is governmentally owned, then the government can assign the trained man power resources who are familiar to work on new machineries, tools and techniques on the

upcoming projects. Documentation is also another means for adopting the transferred technology. This will help as a reference to implement the work on other projects.

Hence, this study proposes a frame work, relating the identified determinants for the success of technology transfer with a project life cycle of a given project and how to be implemented.

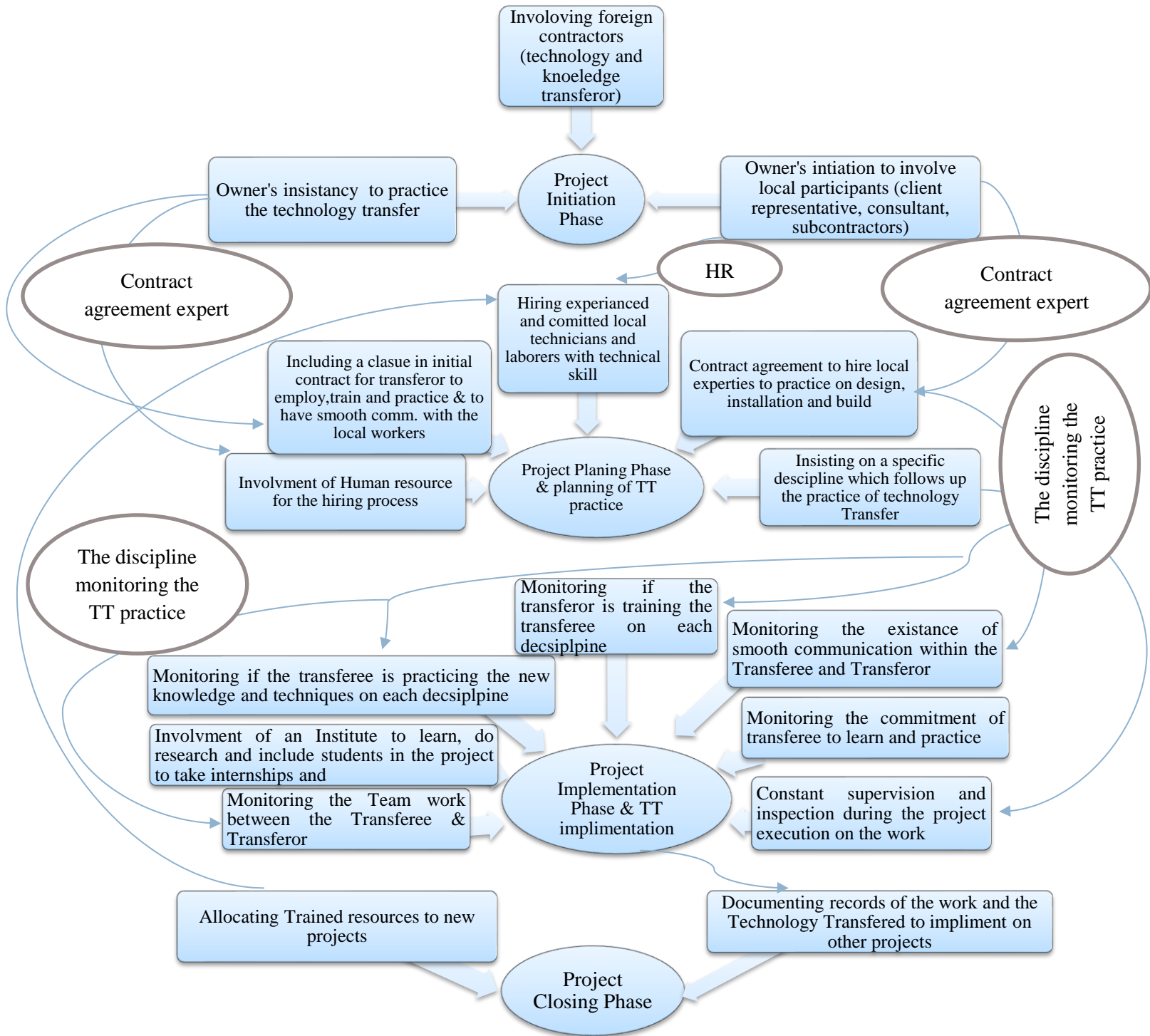


Figure 11: Frame work for implementing technology transfer in project life cycle

**Table 25: The means of verification, variable indicators and responsible body for technology transfer in project life cycle**

No.	Goals	Proposed actions	Responsible body	VI	MV
1	Technicians to learn, practice and adopt new technologies and knowledge from the transferor	Hiring experienced local technicians with capacity and technical skills	Human resource of the contractor, subcontractor (if exist)	Experienced technicians working on construction projects	Checking if the technicians are experienced
2	Local sub-contractors to learn, practice and adopt new technologies and knowledge from transferor	Local sub-contractor involvement on the project	Client of the project, Government enforcement (PPA)	Local sub-contractors working on construction project	Checking on involvement of local-sub contractor
3	Transferee to learn, practice and adopt new technologies and knowledge from transferor	Transferee commitment to learn and practice on site	Technology transfer inspection discipline	Local workers(transferee) committing to learn and practice on a project	Inspecting the hired local workers if they are working with commitment
4	To grasp knowledge and new technology from the transferor	Involving constant supervision and inspection team from local company	Client	Supervision and inspection team working on site consistently	Checking on hiring the local supervision team on the project

5	Transferee to learn, practice and adopt new technologies and knowledge from transferor	Transferor training the transferee for the expected work	Delegated project planning team	Transferor training transferee	Checking on availability of training
			Technology transfer inspection discipline		
6	The success of technology transfer from transferor to transferee on the given project	Need of specific discipline which follows up the effectiveness of technology transfer on site	Client (insisting on the discipline)	Technology transfer inspection team inspecting the transferor & transferee	Checking on the availability of TT from transferor to transferee
			Human resource (hiring the TT inspection team)		
7	The success of technology transfer from transferor to transferee on the given project	Need of previous experience of the local workers in working with international contractors for easiness of TT between the transferor and transferee	Human resource (hiring experienced workers)	Experienced local workers working with foreign contractor (Transferor)	Checking on the smoothness of technology transfer between the transferor and transferee
8	The success of technology transfer from transferor to transferee on the given project	Need of government enforcement (regarding on design, installation and contract agreement) for the knowledge and technology transfer	Technology transfer inspection discipline	Transferor involving local workers starting from design to installation on their field, as per the agreement	Checking on the team work between transferor and transferee
9	The success of technology transfer from transferor to transferee through	Transferor allowing the transferee to practice the new techniques on site	Technology transfer inspection discipline	Local workers (transferee) practicing	Checking on the locals actively working with the transferors

	practicing on the given project			the new technology on site	
10	The success of technology transfer from transferor to transferee	Including a section in initial contract, which insist on for all the local parties to get involved in the project with foreign contractors	Project planner & Technology transfer inspection discipline	Transferee (delegated local parties) working with transferor throughout the project	Checking on the transferee working with transferor as per the agreement
11	The success of technology transfer from transferor to transferee	Need of experienced local expertise and engineers for the success of technology transfer	Human resource (hiring expertise and engineers)	Experienced local workers working with foreign contractor (Transferor)	Checking on the smoothness of technology transfer between the transferor and transferee
12	The success of technology transfer from transferor to transferee	Smooth communication between the Transferee and Transferor	Technology transfer inspection discipline Human resource	Transferee and transferor communicating smoothly	Checking on the communication between the transferee and transferor
13	For the success of knowledge transfer	Involving local institutes to participate for the purpose of learning and do research	Client/ Client representative/ consultant	Local Institutes participating on the project for knowledge transfer	Checking on the participation of local institutes
14	For the success of knowledge transfer	Involvement of Local Experts on Design stage of the project	Client/ Client representative/ consultant	Local designers participating on the design of the project	Checking on the local designers working with the design team of transferor

15	The success of technology transfer from transferor to transferee	Team work between the Transferee and transferor	Technology transfer inspection discipline	Transferor working with transferee on the project as a team	Checking on the team work between the transferor and transferee
16	The success of technology transfer from transferor to transferee	Thorough visitation of local contractors to learn and get experience	Client/ Client representative/ consultant	local contractors visiting the site work	Arranging site visitation and checking the availability of site visitation
17	For smooth technology transfer & knowledge sharing between the transferor and transferee	Need of trust within the transferee and transferor	Client/ Client representative/ consultant	Transferor and transferee working with trust	Checking on smooth r/n ship between the transferee and transferor
18	For smooth technology transfer between the transferor and transferee	Willingness of Transferor to teach and give trainings to the local employees	Technology transfer inspection discipline	Transferor willingly teaching and giving training to the transferee	Checking on transferee being trained

## **CHAPTER 7**

### **CONCLUSION AND RECOMMENDATION**

#### **7.1 Conclusion**

In this study first, the major factors/determinants for the success of technology transfer were identified through literature review and the factors were ranked by local experts, engineers and laborers from both client representative and local employees of the foreign contractor's side through questionnaire survey. To analyze whether there is a technology transfer or not in the given study case, questionnaire was developed and respondents were able to give us where the gap relies on. Furthermore, a frame work was developed for the identified and ranked determinants as per their importance to be implemented in project life cycle. Based on the survey and analysis made in this study the following conclusions are put forward:

1. The factors/determinants for the success of technology transfer from both client representative and local workers of the contractor's perspective were analyzed, and their respective rankings were made that allows the responsible part to consider in implementing on the project life cycle.
2. Frame work was developed by implementing the ranked determinants/factors of technology transfer on a project life cycle.

#### **7.2 Recommendation**

Through the literature review, it was found different factors for the success of technology transfer. These determined factors were considered and questionnaire for both the transfer or and transferee was distributed to determine and rank their importance with regard to their practice on the selected site and in general aspect for the need of the technology transfer. The result has been shown and a frame work was developed which guides the implementation of the determined technology transfer on the project life cycle of a given project. This is important first to know what are the main factors that must be considered for the process of TT, to consider the need of the technology transfer, the need to actually practice the expected and necessary new technologies, need to monitor and evaluate how much is being practiced and is actually adopted.

### **7.3 Recommendation**

Based on the result and conclusion discussed above the following recommendations are forwarded:

1. As a developed country, the construction industry of Ethiopia must practice the technology transfer for the advantage to increase the development of construction industry.
2. The main factors for the success of technology transfer that are identified and ranked must be used when working on future projects.
3. The local government, client, as well as the workers must be smart to use the opportunity to get the necessary technology, knowledge/skill from the foreign/international contractor working on the project.
4. There needs to be a strategy or a framework for the future work to practice the technology transfer starting from the beginning of the project until the end and must be monitored throughout the project.

## Reference

- BL Kedia, R. B. (1988). Cultural constraints on transfer of technology across nations: Implications for research in international and comparative management. *Academy of Management Review*.
- Buckley, J. (1985). "Ranking alternatives using fuzzy numbers," *Fuzzy sets and systems*.
- D Bennett, H. Z. (2004). International technology transfer: perceptions and reality of quality and reliability. *Journal of Manufacturing Technology*.
- DG Owusu-Manu, E. P.-A. (2017). Modelling a conceptual framework of technology transfer process in construction projects: an empirical approach. *Journal of construction engineering*.
- Ganesan, K. D. (2002). Technology transfer subcontracting in developing countries through. *Building Research & Information*, Volume 30, 2002 .
- Hagopian, M. F. (1984). The construction industry and economic growth. *Asian National Development*.
- Harv, D. H. (1991). International transfer of technology: Lessons that East Europe can learn from the failed Third World experience. *HeinOnline*.
- Hillebrandt, P. M. (2001). *Economic Theory and the Construction Industry*. Palgrave Macmillan, a division of Macmillan Publishers Limited 2000.
- J Zeng, M. A. (2007). Application of a Fuzzy Based Decision Making Methodology to Construction Project Risk Assessment. *International journal of project management*.
- Lin, C. T. (2002). The critical factors for technology absorptive capacity. *Industrial Management & Data Systems*.
- Luo, G. a. (2017).
- Mardani, A., Jusoh, A., Zavadskas, E., Cavallaro, F., & Khalifah, Z. (2015). Sustainable and renewable energy: An overview of the application of multiple criteria decision making techniques and approaches. *Sustainability*.
- Ministry of Urban Development and Construction . (2012). A.A.
- MM Kumaraswamy, G. S. (2000). Problems in Technology Transfer vs Potential for Technology Exchange: A Hong Kong construction perspective'. *The Economist Publications Ltd., UK*.
- Mselle, J. (2014). An Evaluation of Enabling Factors for Technology Transfer in Tanzania Construction Industry. *International Journal of Construction Engineering and Management*.
- NM Reddy, L. Z. (1990). *International technology transfer: A review*. Published by Elsevier B.V.
- Odedra, M. (1991). Information technology transfer to developing countries: IS it really taking place? *North-Holland*.

- Ofori, G. ( 2006). Revaluing Construction in Developing Countries. Journal of construction in developing countries.
- Ofori, G. (2001). Challenges facing the construction industries of Southern Africa. Construction Management and Economics.
- Prabhakar, B. S. (2010). A Simplified Description of Fuzzy TOPSIS. Dept. of Computer Science and Engineering, IIT Kanpur, UP 208016 India.
- R Takim, R. O. (2009). International technology transfer (ITT) projects and development of technological capabilities in Malaysian construction industry: A conceptual framework. Asian Social Science.
- reliability, I. t. (2004). D Bennett, H Zhao. Journal of Manufacturing Technology .
- Rodney A. Stewart, T. W. (2007). Benchmarking construction technology transfer in Thailand. Emerald Group Publishing Limited.
- S Ganesan, J. K. (2006). Technology transfer: international collaboration in Sri Lanka. Construction Management and Economics.
- Shrestha, M. M. (2002). Targeting 'technology exchange' for faster organizational and industry development. Building Research & Information .
- Simkoko, E. (1992). Managing international construction projects for competence development within local firms. International Journal of Project Management.
- Sridharan, G. (1994). Managing technology transfer in construction joint ventures. Copyright American Association of Cost Engineers .
- T Waroonkun, R. S. (2008). Modeling the international technology transfer process in construction projects: evidence from Thailand. The Journal of Technology Transfer.
- Tatum, C. (1986). Potential mechanisms for construction innovation. Journal of Construction Engineering and Management.
- Tatum, C. (1988). classification system for construction technology. Journal of Construction Engineering and Management.
- Toakley, A. L. (1991). Risk Management and the Building Procurement Process. Proceedings of Innovation and Economics in Building Conference, 23-24 September, (pp. pp. 63-7). Brisbane.
- V Kumar, U. K. (n.d.). Building technological capability through importing technology: the case of Indonesian manufacturing industry. he Journal of Technology.
- Vincke, P. (1992). Multicriteria Decision Aid. New York: Wiley.
- Zavadskas, E. K. (2011). Multiple Criteria Decision Making (MCDM) Methods in Economics: An Overview. UK: Taylor & Francis.

- Gebrehiwet, T. and H. Luo (2017). "Analysis of Delay Impact on Construction Project Based on RII and Correlation Coefficient: Empirical Study." *Procedia Engineering* **196**: 366-374.
- BL Kedia, R. B. (1988). Cultural constraints on transfer of technology across nations: Implications for research in international and comparative management. *Academy of Management Review*.
- Buckley, J. (1985). "Ranking alternatives using fuzzy numbers," *Fuzzy sets and systems*.
- D Bennett, H. Z. (2004). International technology transfer: perceptions and reality of quality and reliability. *Journal of Manufacturing Technology*.
- DG Owusu-Manu, E. P.-A. (2017). Modelling a conceptual framework of technology transfer process in construction projects: an empirical approach. *Journal of construction engineering*.
- Ganesan, K. D. (2002). Technology transfer subcontracting in developing countries through. *Building Research & Information*, Volume 30, 2002 .
- Hagopian, M. F. (1984). The construction industry and economic growth. *Asian National Development*.
- Harv, D. H. (1991). International transfer of technology: Lessons that East Europe can learn from the failed Third World experience. *HeinOnline*.
- Hillebrandt, P. M. (2001). *Economic Theory and the Construction Industry*. Palgrave Macmillan, a division of Macmillan Publishers Limited 2000.
- J Zeng, M. A. (2007). Application of a Fuzzy Based Decision Making Methodology to Construction Project Risk Assessment. *International journal of project management*.
- Lin, C. T. (2002). The critical factors for technology absorptive capacity. *Industrial Management & Data Systems*.
- Luo, G. a. (2017).
- Mardani, A., Jusoh, A., Zavadskas, E., Cavallaro, F., & Khalifah, Z. (2015). Sustainable and renewable energy: An overview of the application of multiple criteria decision making techniques and approaches. *Sustainability*.
- Ministry of Urban Development and Construction . (2012). *A.A.*
- MM Kumaraswamy, G. S. (2000). Problems in Technology Transfer vs Potential for Technology Exchange: A Hong Kong construction perspective'. *The Economist Publications Ltd., UK*.
- Mselle, J. (2014). An Evaluation of Enabling Factors for Technology Transfer in Tanzania Construction Industry. *International Journal of Construction Engineering and Management*.
- NM Reddy, L. Z. (1990). *International technology transfer: A review*. Published by Elsevier B.V.
- Odedra, M. (1991). Information technology transfer to developing countries: IS it really taking place? *North-Holland*.

- Ofori, G. ( 2006). Revaluing Construction in Developing Countries. Journal of construction in developing countries.
- Ofori, G. (2001). Challenges facing the construction industries of Southern Africa. Construction Management and Economics.
- Prabhakar, B. S. (2010). A Simplified Description of Fuzzy TOPSIS. Dept. of Computer Science and Engineering, IIT Kanpur, UP 208016 India.
- R Takim, R. O. (2009). International technology transfer (ITT) projects and development of technological capabilities in Malaysian construction industry: A conceptual framework. Asian Social Science.
- reliability, I. t. (2004). D Bennett, H Zhao. Journal of Manufacturing Technology .
- Rodney A. Stewart, T. W. (2007). Benchmarking construction technology transfer in Thailand. Emerald Group Publishing Limited.
- S Ganesan, J. K. (2006). Technology transfer: international collaboration in Sri Lanka. Construction Management and Economics.
- Shrestha, M. M. (2002). Targeting 'technology exchange' for faster organizational and industry development. Building Research & Information .
- Simkoko, E. (1992). Managing international construction projects for competence development within local firms. International Journal of Project Management.
- Sridharan, G. (1994). Managing technology transfer in construction joint ventures. Copyright American Association of Cost Engineers .
- T Waroonkun, R. S. (2008). Modeling the international technology transfer process in construction projects: evidence from Thailand. The Journal of Technology Transfer.
- Tatum, C. (1986). Potential mechanisms for construction innovation. Journal of Construction Engineering and Management.
- Tatum, C. (1988). classification system for construction technology. Journal of Construction Engineering and Management.
- Toakley, A. L. (1991). Risk Management and the Building Procurement Process. Proceedings of Innovation and Economics in Building Conference, 23-24 September, (pp. pp. 63-7). Brisbane.
- V Kumar, U. K. (n.d.). Building technological capability through importing technology: the case of Indonesian manufacturing industry. he Journal of Technology.
- Vincke, P. (1992). Multicriteria Decision Aid. New York: Wiley.
- Zavadskas, E. K. (2011). Multiple Criteria Decision Making (MCDM) Methods in Economics: An Overview. UK: Taylor & Francis.

## **ANNEX**

## **ANNEX 1: Questionnaire**

Dear Sir or Madam,

I would like to invite you to take part in an MSc research work on technology transfer in construction project on case study of CBE HQ project using fuzzy logic from owners and a contractor perspective. The main objective of the questionnaire is to identify the factors (determinants) for an effective technology transfer and adaptation which is found from working with the foreign contractors (CSCEC).

I hope you can give your input to this research which is MSc thesis that is being conducted in Addis Ababa Institute of Technology Department of Industrial Engineering. With your kind participation, I hope to understand, identify and rank the major factors/ determinants for technology transfer in CBE HQ construction project.

So please spare your time out of your busy schedule to complete this questionnaire, that should not take more than 30 minutes of your valuable time.

Yours Sincerely,

Melat Solomon

MSc Student AAiT

Tel No.: 0911446309/0945540904

June 2018

## SURVEY

This survey is being undertaken by a research student from Addis Ababa Institute of Technology Department of Mechanical and Industrial Engineering, Industrial Engineering major.

The general objectives of this survey is to assess and improve the process of risk analysis techniques currently being practiced in Ethiopian road construction industries by identifying and assessing key risk factors that have high likelihood of occurrence and degree of impact on road construction projects and prioritizing them in accordance with cost contingency estimation.

The specific objectives of the research are:

- Identify major factors/determinants for the success of technology and weigh their importance on a given project where there is a practice of transferor and transferee working together.
- Deliver a method for gaining consistent measures for each factors/determinant for the success of Technology Transfer.
- Providing a Frame work relating the identified and weighted determinants/factors as per every respondent work experience with project life cycle to implement and practice technology transfer successfully.
- Providing practical suggestions and recommendations on improving the technology transfer process and to practice the new technologies on our own after adopting the needed new technology and knowledge through time.

### **INSTRUCTIONS FOR COMPLETING THE QUESTIONNAIRE:**

- For questions which require an opinion, there is a grid of line to show grades of opinion. Please mark the box which most closely fits your opinion.
- Only one answer is required for each question
- **ONLY** if you do not fully understand a question or it is unclear neglect and move on to the next, **OTHERWISE** please answer the best possible choice.
- Any information provided in this questionnaire will be treated in strict confidence.

## PART I RESPONDENT PROFILE

1. The position of the respondent

Quantity Surveyor	<input type="checkbox"/>	Project Manager	<input type="checkbox"/>
Architects	<input type="checkbox"/>	Site Manager	<input type="checkbox"/>
Office Engineer	<input type="checkbox"/>		
Other	_____		

2. Experience and Educational Qualifications

Education level: \_\_\_\_\_

Working Experience in years (In the sector): \_\_\_\_\_

Working Experience in years (In current position): \_\_\_\_\_

**PART II RESPONDENT PROFILE ON THE PROJECT**

Description of duty	New technology/knowledge practiced or learned (√)	Project involvement
Resident engineer	<input type="checkbox"/> Management <input type="checkbox"/> Practical Skill <input type="checkbox"/> Engineering /Technical Skill <input type="checkbox"/> New techniques (tools & machines) used for construction <input type="checkbox"/> Design	<input type="checkbox"/> As a Client <input type="checkbox"/> As a Contractor <input type="checkbox"/> As a client representative <input type="checkbox"/> As a contractor employee
Quality and safety manager	<input type="checkbox"/> Management <input type="checkbox"/> Practical Skill <input type="checkbox"/> Technical Skill <input type="checkbox"/> New techniques (tools & machines) used for construction <input type="checkbox"/> Design	<input type="checkbox"/> As a Client <input type="checkbox"/> As a Contractor <input type="checkbox"/> As a client representative <input type="checkbox"/> As a contractor employee
Contract specialist	<input type="checkbox"/> Management <input type="checkbox"/> Practical Skill <input type="checkbox"/> Technical Skill <input type="checkbox"/> New techniques (tools & machines) used for construction <input type="checkbox"/> Design	<input type="checkbox"/> As a Client <input type="checkbox"/> As a Contractor <input type="checkbox"/> As a client representative <input type="checkbox"/> As a contractor employee

Office engineer	<input type="checkbox"/> Management <input type="checkbox"/> Practical Skill <input type="checkbox"/> Technical Skill <input type="checkbox"/> New techniques (tools & machines) used for construction <input type="checkbox"/> Design	<input type="checkbox"/> As a Client <input type="checkbox"/> As a Contractor <input type="checkbox"/> As a client representative <input type="checkbox"/> As a contractor employee
Structural/civil engineer	<input type="checkbox"/> Management <input type="checkbox"/> Practical Skill <input type="checkbox"/> Technical Skill <input type="checkbox"/> New techniques (tools & machines) used for construction <input type="checkbox"/> Design	<input type="checkbox"/> As a Client <input type="checkbox"/> As a Contractor <input type="checkbox"/> As a client representative <input type="checkbox"/> As a contractor employee
Material /civil engineer	<input type="checkbox"/> Management <input type="checkbox"/> Practical Skill <input type="checkbox"/> Technical Skill <input type="checkbox"/> New techniques (tools & machines) used for construction <input type="checkbox"/> Design	<input type="checkbox"/> As a Client <input type="checkbox"/> As a Contractor <input type="checkbox"/> As a client representative <input type="checkbox"/> As a contractor employee
Quantity surveyor and cost engineer	<input type="checkbox"/> Management <input type="checkbox"/> Practical Skill <input type="checkbox"/> Technical Skill <input type="checkbox"/> New techniques (tools & machines) used for construction	<input type="checkbox"/> As a Client <input type="checkbox"/> As a Contractor <input type="checkbox"/> As a client representative <input type="checkbox"/> As a contractor employee

	<input type="checkbox"/> Design	
Surveyor	<input type="checkbox"/> Management <input type="checkbox"/> Practical Skill <input type="checkbox"/> Technical Skill <input type="checkbox"/> New. techniques (tools & machines) used for construction <input type="checkbox"/> Design	<input type="checkbox"/> As a Client <input type="checkbox"/> As a Contractor <input type="checkbox"/> As a client representative <input type="checkbox"/> As a contractor employee
Design team	<input type="checkbox"/> Management <input type="checkbox"/> Practical Skill <input type="checkbox"/> Technical Skill <input type="checkbox"/> New techniques (tools & machines) used for construction <input type="checkbox"/> Design	<input type="checkbox"/> As a Client <input type="checkbox"/> As a Contractor <input type="checkbox"/> As a client representative <input type="checkbox"/> As a contractor employee
Mechanical site engineer	<input type="checkbox"/> Management <input type="checkbox"/> Practical Skill <input type="checkbox"/> Technical Skill <input type="checkbox"/> New techniques (tools & machines) used for construction <input type="checkbox"/> Design	<input type="checkbox"/> As a Client <input type="checkbox"/> As a Contractor <input type="checkbox"/> As a client representative <input type="checkbox"/> As a contractor employee

<p>Electrical site engineer</p>	<input type="checkbox"/> Management <input type="checkbox"/> Practical Skill <input type="checkbox"/> Technical Skill <input type="checkbox"/> New techniques (tools & machines) used for construction <input type="checkbox"/> Design	<input type="checkbox"/> As a Client <input type="checkbox"/> As a Contractor <input type="checkbox"/> As a client representative <input type="checkbox"/> As a contractor employee
<p>Plumbing and firefighting site engineer</p>	<input type="checkbox"/> Management <input type="checkbox"/> Practical Skill <input type="checkbox"/> Technical Skill <input type="checkbox"/> New techniques (tools & machines) used for construction <input type="checkbox"/> Design	<input type="checkbox"/> As a Client <input type="checkbox"/> As a Contractor <input type="checkbox"/> As a client representative <input type="checkbox"/> As a contractor employee
<p>Civil site inspectors</p>	<input type="checkbox"/> Management <input type="checkbox"/> Practical Skill <input type="checkbox"/> Technical Skill <input type="checkbox"/> New techniques (tools & machines) used for construction <input type="checkbox"/> Design	<input type="checkbox"/> As a Client <input type="checkbox"/> As a Contractor <input type="checkbox"/> As a client representative <input type="checkbox"/> As a contractor employee
<p>Mechanical site inspectors</p>	<input type="checkbox"/> Management <input type="checkbox"/> Practical Skill <input type="checkbox"/> Technical Skill <input type="checkbox"/> New techniques (tools & machines) used for construction	<input type="checkbox"/> As a Client <input type="checkbox"/> As a Contractor <input type="checkbox"/> As a client representative <input type="checkbox"/> As a contractor employee

	<input type="checkbox"/> Design	
Electrical site inspectors	<input type="checkbox"/> Management <input type="checkbox"/> Practical Skill <input type="checkbox"/> Technical Skill <input type="checkbox"/> New techniques (tools & machines) used for construction <input type="checkbox"/> Design	<input type="checkbox"/> As a Client <input type="checkbox"/> As a Contractor <input type="checkbox"/> As a client representative <input type="checkbox"/> As a contractor employee
Plumbing and firefighting site inspectors	<input type="checkbox"/> Management <input type="checkbox"/> Practical Skill <input type="checkbox"/> Technical Skill <input type="checkbox"/> New techniques (tools & machines) used for construction <input type="checkbox"/> Design	<input type="checkbox"/> As a Client <input type="checkbox"/> As a Contractor <input type="checkbox"/> As a client representative <input type="checkbox"/> As a contractor employee
Architects	<input type="checkbox"/> Management <input type="checkbox"/> Practical Skill <input type="checkbox"/> Technical Skill <input type="checkbox"/> New techniques (tools & machines) used for construction <input type="checkbox"/> Design	<input type="checkbox"/> As a Client <input type="checkbox"/> As a Contractor <input type="checkbox"/> As a client representative <input type="checkbox"/> As a contractor employee

Laborer	<input type="checkbox"/> Management	<input type="checkbox"/> As a Client
	<input type="checkbox"/> Practical Skill	<input type="checkbox"/> As a Contractor
	<input type="checkbox"/> Technical Skill	<input type="checkbox"/> As a client representative
	<input type="checkbox"/> New techniques (tools & machines) used for construction	<input type="checkbox"/> As a contractor employee
	<input type="checkbox"/> Design	

Item	Transferee (Engineers) opinion about the transferor	Rating your opinion (√)				
		Very Low	Low	Moderate	High	Very High
1	Willingness of foreign contractors to teach and give trainings to the local employees					
2	Smooth Communication and understanding with the transferor					
3	Trust between the transferor network with transferee					
4	Consultant or other discipline which follows up the practice of Technology Transfer					

Item	Transferee opinion about the transferor (From the Laborers)	Rating your opinion (√)				
		Very Low	Low	Moderate	High	Very High

1	Willingness of foreign contractors to teach and give trainings to the local employees					
2	Smooth Communication and understanding with the transferor					
3	Trust between the transferor network with transferee					
4	Consultant or other discipline which follows up the practice of Technology Transfer					
Item	Transferor opinion about the transferee (From the Experts)	Rating your opinion (√)				
		Very Low	Low	Moderate	High	Very High
1	Willingness of transferee to learn					
2	Commitment of the workers					
3	Constant inspection from the local company					
4	Understanding level of transferee of new technology/techniques/skills					

Item	<b>Determinants/ factors of Technology Transfer (Alternatives)</b>	Rating your opinion (√)				
		Very Low	Low	Moderate	High	Very High
1	Hiring experienced local technicians with capacity and technical skills					
2	Local sub-contractor involvement on the project					
3	Transferee commitment to learn and practice on site					
4	Involving constant supervision and inspection team from local company					
5	Transferor training the transferee for the expected work					
6	Need of specific discipline which follows up the effectiveness of technology transfer on site					
7	Need of previous experience of the local workers in working with international contractors					
8	Need of government enforcement (regarding on design, installation and contract agreement)					

	for the knowledge and technology transfer					
9	Transferor allowing the transferee to practice the new techniques on site					
10	Including a section in initial contract, which insist on for all the local parties to get involved in the project with foreign contractors					
11	Need of experienced expertise and engineers for the success of technology transfer					
12	Smooth communication between the Transferee and Transferor					
13	Involving local institutes to participate for the purpose of learning and do research					
14	Involvement of Local Experts on Design stage of the project					
15	Team work between the foreign and local firm					
16	Thorough visitation of local contractors to learn and get experience					
17	Need of trust within the transferee and transferor					

18	Willingness of Transferor to teach and give trainings to the local employees					
----	--	--	--	--	--	--