JIMMA UNIVERSITY

JIMMA INSTITUTE OF TECHNOLOGY

FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING

CONSTRUCTION ENGINEERING AND MANAGEMENT STREAM

ASSESSMENT ON EFFECTIVENESS OF PRECAST AND CAST-IN-SITU CONCRETE IN BUILDING CONSTRUCTION: CASE STUDY IN MEKELE CITY

A THESIS SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES OF JIMMA UNIVERSITY IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN CIVIL ENGINEERING (CONSTRUCTION ENGINEERING AND MANAGEMENT)

By: Gebremicael Tetemke

January 2020

Jimma, Ethiopia

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SCHOOL OF GRADUATE STUDIES

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CONSTRUCTION ENGINEERING AND MANAGEMENT CHAIR

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DECLARATION

I declare that this thesis entitled "assessment on effectiveness of precast and cast-in-situ concrete in building construction: case study in Mekelle city" was my original work. I confirmed that this was my own work and the use of all materials from other sources have been properly cited.

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ABSTRACT

Prefabrication is defined as the production of entire building, or significant building constituents offsite in a workshop and transported for assembly to construction site. Prefabrication is a very beneficial construction approach with widely accepted benefits including shorter project duration, reduced project cost, improved quality product, enhanced control of construction activities, improved safety of workers and environmental friendliness compared to conventional method.

There is a huge gap on the demand and supply of residential houses and quality problem in our country especially to concrete structural elements & delays in construction of building projects are common, and its price is not affordable by majority of population. It is an undisputable fact that, stakeholder's of construction industry (clients, consultants, and contractors) do not highly work on prefabrication methods of construction leaving the construction industry to continue to heavily depend on in-situ construction, which does not encourage diversity in the method of construction and that's why most of construction companies entitled to delay, cost overrun and sub-standard quality

The objective of this study was to assess the effectiveness of precast and cast in-situ concrete method in building construction projects. The research made use of literature review of existing work. Questionnaires administered to respondents and interview of selected stakeholders in the construction industry. The statistical tools used in the analysis comprised descriptive statistics using tables and graphs. RII was used to analyze the qualitative data's, and, the selection of samples from the total population were non-probabilistic sampling, and selection of stakeholders was purposive.

For this study, the total duration and total cost estimation per cubic meter have been determined for both prefabricated and cast in-situ concrete construction and prefabrication is effective in terms of time and cost (have 62.9% reduced time offered and 12% less cost) and have better quality since these materials are produced in controlled environment i.e. easy for control. Since prefabrication method of construction is a new method, future research in to the concept of prefabrication should be conducted in order to solve the misunderstanding of stakeholders and the government and investors should work together to handle the high demand of home at short period, small budget and specified quality.

Key Words: industrialization, modularization, prefabrication, project success.

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ACRONYMS

CBO	~	Community Based Organization
DC	~	Data Collector
ECWC	~	Ethiopian construction works corporation
JIT	~	Jimma Institute of Technology
KG	~	Kilogram
KM	~	Kilometer
N	~	Northing direction
NGO	~	Non-Governmental Organization
PBPPE	~	Prefabricated Building Parts Production Enterprise
PI	~	Principal Investigator
PREFAB	~	Prefabrication
RC	~	Reinforced Concrete
RCC	~	Reinforced Cement Concrete
RII	~	Relative Importance Index

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1. INTRODUCTION

1.1 Background

Construction work is performed in two different ways, namely, using either traditional construction processes or offsite construction. Offsite construction refers to prefabricated material and components fabricated and or pre-assembled in a factory-type working environment followed by transportation to their permanent location on site. Offsite production is also recognized under various names, for example, modularization, pre-assembly, prefabrication or precast. Conversely, traditional construction work is carried out on site through the combinations of manual labour and raw materials. Traditional construction methods are referred to as labour based, labour intensive or in-situ construction methods. The in-situ construction method is construction work which uses raw materials and involves labour intensity on the building site (Haas et al, 2000).

According to Hampson & Brandon, (2004) Prefabrication may be defined here as the production of entire building, or significant building constituents offsite in a workshop background prior to fixing or assembly onsite. This is a favorable invention with a clear correlation to more ecologically pleasant construction practices.

Prefabricated and cast-in-situ building systems are widely adopted in public buildings as well as in private building projects. The standardization and mechanization has brought a substantial change in the development of the construction industry worldwide over last few decades. With the adoption of more mechanization, computer aided manufacturing, and intelligent management systems, the extensive use of prefabrication contributed to sustainable development by using cleaner and more resources saving production process (Dineshkumar and Kathirvel, 2015). Tam et al. (2007) also revealed that the use of prefabrication reduces waste arising from plastering, timber formwork and concrete works by about 100%, 74%–87% and 51%–60%, respectively. Although the magnitude of waste reduction depends on the level of prefabrication, waste levels have an average reduction of 65% and up to 70% when compared with on-site construction method.

Lu, (2009) states about the advantage of prefabrication concrete as, Prefabrication is a very beneficial construction approach with widely accepted benefits including shorter project duration, reduced project cost, improved quality product, enhanced control of construction activities, enhanced safety of workers and environmental friendliness compared to conventional method. BABU et al. (2013) summarizes as Prefabricated concrete have better quality than cast in-situ since they produced In a climate-controlled environment using efficient equipment operated by well-trained people but cast in situ concrete may have low qualities due to Uncertain weather can result in less-than expected construction.

According to Samson (2017), a huge gap remains in the housing market, and the needs of the middle-income urban population in Addis Ababa. Accordingly adopting the latest and advantageous construction method (prefabrication) is essential for growing real estate construction sector of Addis Ababa. He also state as prefabricated elements are produced under controlled environment, they have better quality with standard and its construction method offer limited time and lesser cost it is advantageous to address the demand of middle-income population.

Therefore, the aim of this study was to assess the awareness of stakeholders in the building construction industry about prefabrication and to analyze the Time reduction, cost savings, and the quality improvements achievable via the effectiveness of one on the other in concrete building system.

1.2 Statement of the Problem

The use of prefabricated components in the management of building construction works in our country is rare, meanwhile, the use of prefabricated components; highly contribute to the industrialization of the construction industry. Its undisputable fact that, stakeholder's of construction industry (clients, consultants, and contractors) do not highly work on prefabrication methods of construction, leaving the construction industry to continue and heavily depend on in-situ construction, which does not encourage diversity in the method of construction and that's why most of construction companies entitled to delay, cost overrun and sub-standard quality (Shreyanka and Ashwin, 2017).

Samson (2017) states existence of huge gap on the demand and supply of houses and existence of quality problem in Addis Ababa real estate construction especially to concrete structural elements & delays in construction of real estate projects are common in Addis Ababa, and its price is not affordable by majority of population and as time is one of the main factors in construction industry, time-overrun affects the overall cost of the project by additional overhead cost, change of material price because of additional time and inflation.

Construction methods that require a lot of physical labor such as masonry, temporary work, hand paint or cast-in-place concrete are common in several countries and their construction industry is entitled for many problems like cost overrun, delay, sub-standard qualities, on-site safety and health problems, energy and material waste during a construction (Shreyanka and Ashwin, 2017).

Even if Delay, cost overrun and substandard quality of concrete structures was common practice in Ethiopian construction industry, better to work on handling the causes of those critical constraints starting from the method of construction used (precast or cast in-situ).

1.3 Research Questions

The study sought to answer the following questions on how to differentiate precast and cast in-situ concrete in building construction based on the triple constraints (time, cost and quality).

- What is the attitude of the stakeholders in building construction for precast concrete?
- What are the time, cost related benefits of precast concrete and cast in-situ in building construction projects?
- What are the quality-related benefits of precast concrete and cast in-situ in building construction projects?

1.4 Research Objectives

- The General objective of this study was to assess the effectiveness of precast and cast in-situ concrete method in building construction projects around **Mekelle** city.
- Specific objectives;
    - To assess the awareness of the construction stakeholders in building construction about prefabrication concrete
    - To identify the time and cost related benefits of precast concrete and cast in-situ in building construction projects

- To identify the quality-related benefits of precast concrete and cast in-situ in building construction projects

1.5 Significance of the Study

This study was essential in the sense that, it would not only contribute to knowledge and theory, but would also bring to bear the promotion of the effective method of concrete construction (precast or cast in-situ) for construction works in our country and how these systems impact on time, cost and quality of projects. So that the appropriate government agencies and the General-public would be familiar with the situation and hence can save the huge amount of resources wasting through the inappropriate method of construction.

The study would be relevant to Non-governmental Organizations (NGOs) and Community Based Organizations (CBOs), government and the private sector and other players in the construction industry to realize the effective method of construction for their projects. Most researchers argued that most of the construction projects in our country are entitled to delay and cost overrun and huge amount of resources of the country are wasting, that is why I select this topic.

1.6 Scope and Limitation of the Study

The study of the adoption of prefabrication for construction projects has many benefits. Any construction project has some basic parameters to meet, notably among them are productivity, time, cost, quality, safety, socio-economic aspects (labour), environmental performance and client satisfaction. The scope of this study was limited to time, cost and quality only in the management of construction works.

The area of study was limited to Building concrete construction. This research also placed much prominence on how to improve and promote the adoption and utilization of the usage of prefabricated method of construction in Ethiopia especially in **Mekelle** city. This were cover modules such as columns, beams, floors slabs, walls, staircase, girders and other elements of prefabrication.

2. LITRATURE REVIEW

2.1 Brief history of Concrete Prefabrication

Prefabrication has been used since ancient times. The Sweet Track constructed in England around 3800 BC, employed prefabricated timber sections. Sinhalese kings of ancient Sri Lanka have used prefabricated buildings technology to erect giant structures. In 19th century in Australia, a large number of prefabricated houses were imported from the United Kingdom. The method was widely used in the construction of prefabricated housing in the 20th century, like in the United Kingdom to replace houses bombed during World War II. Assembling sections in factories saved time on-site and reduced cost. The Crystal Palace, erected in London in 1851, was made of iron and glass prefabricated construction (Holla et al. 2016).

The sector seems to have a future (bright or not, only time can show) but the big question that arises is “How can one decide whether or not to use prefabrication in a project?” The decision is not an easy one, as a series of potentially interdependent factors influence the process. This study attempts to focus on a more specific decision-making question: “How does one decide whether or not to use prefabricated concrete structures in a building project?” By focusing on a more specific component, we hope to address the issue better by identifying all factors that influence such a decision. Others have approached the issue as well. Several attempts have been made to identify value components of the construction process. The major advantages reported were better supervision, frozen design at an early stage, reduced construction costs and shortened construction time. On the other hand, the major disadvantages were inflexibility for design changes, lack of research information and higher initial construction costs (Tam et al., 2007).

Moreover, beside the Egyptians who used concrete for their construction works, the use of modern concrete (with aggregate) started in 1756 (Bellis, 2011). Concrete is one of the best commonly used construction materials, usually in the form of in-situ. It is also on record that, precast concrete construction was invented in 1905 by John Alexander Brodie (John Alexander Brodie, England City Engineer (1858-1934), 2011) and this technology was replicated in America and Europe and later the rest of the world.

As opined by Pasquireet al. (2005) that, data of precast concrete projects are generally undocumented and that decisions to use precast concrete elements are not based on well-defined information. There is very little, if any, quantitative comparisons that project teams (client, engineers, and contractor) can apply to consider precast concrete as an option for the construction of buildings.

2.2. Type of Precast system

Depending on the load bearing structure precast systems can be divided into the following categories (Mire & Singh, 2017).

(a) Large Panel System:

This system refers to multi-story structures composed of large walls and floor concrete panels connected in the vertical and horizontal directions so that the wall panels enclose appropriate spaces for the rooms with a building. These panels form a bond like structure. Both horizontal and vertical panels resists gravity loads. Wall panels are usually one story high. Horizontal floor and roof panels span either as one-way or two-way slabs. When properly joined together, these horizontal elements act as diaphragms that transfer the lateral loads to the walls.

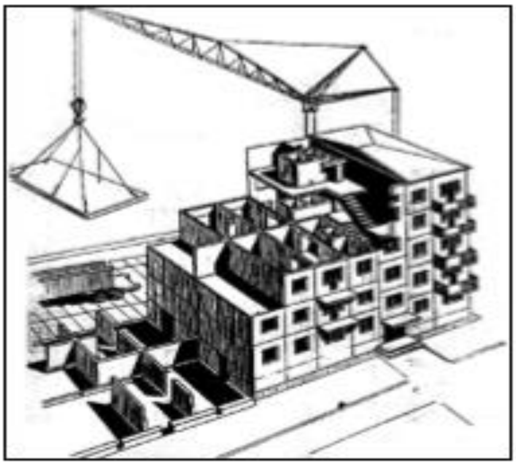

Figure 2.1 large-panel concrete building under construction

(b) Frame Structure:

Precast frames can be constructed using either linear elements or spatial beam-column sub assemblages. Precast beam-column sub-assemblages have the advantages that the connecting faces between the sub-assemblages can be placed away from the critical frame regions; however, linear elements are generally preferred because of the difficulties associated with forming, handling and erecting spatial elements. The use of linear elements generally means placing the connecting faces at the beam-column junctions. The beams can be seated on corbels at the columns, for ease of construction and to aid the shear transfer from the beam to the column. The beam-column joints accomplished in this way are hinged. However, rigid beam-column connections are used in some cases, when the continuity of longitudinal reinforcement through the beam-column joint needs to be ensured. The components of a precast reinforced concrete frame are shown in Figure below.

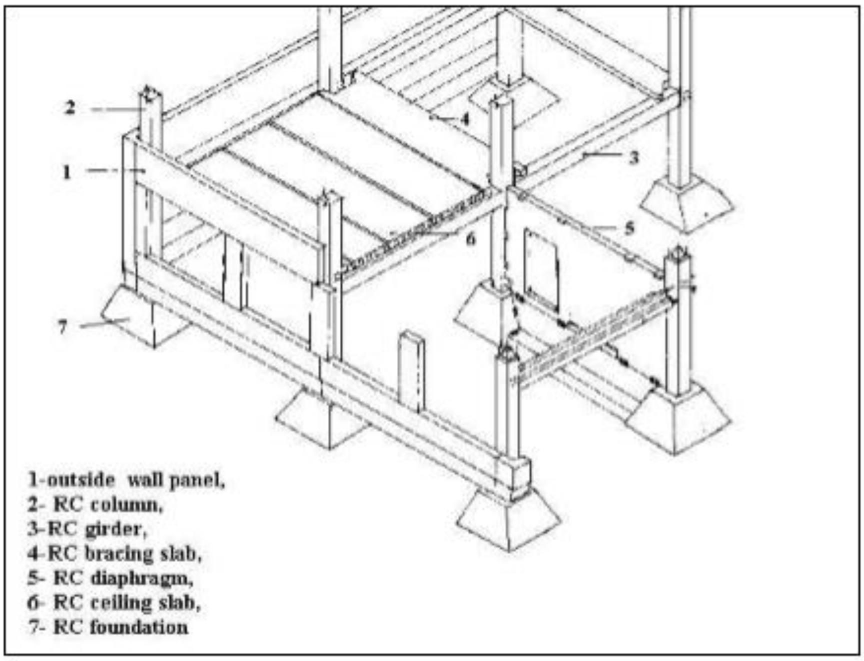

Figure 2.2 Components of a precast reinforced concrete frame system

(c) Slab-Column system with Shear wall:

These systems rely on shear walls to sustain lateral load effects, whereas the slab-column structure resists mainly gravity loads. There are two main systems in this category:

(i) Lift slab system with walls: In this system, the load bearing structure consists of precast reinforcement concrete columns and slabs. Precast columns are usually two stories high. All precast structural elements are assembled by means of special joints.

(ii) Pre stressed slab-column system: In pre-stressed slab-column system uses horizontal pre-stressing in two orthogonal directions to achieve continuity. The precast column elements are 1 to 3 stories high. The reinforcement concrete floor slabs fit the clear span between columns.

Figure 2.3 lift-slab building

Following are some elements of Precast

- Precast Slab
- Precast Walls
- Precast Beam and Girders
- Precast Stairs
- Precast Columns

(d) mixed system

This method is combination of the above

2.3 Time, Cost and Quality Constraints and Project Success

According to the PMBOK Guide, a project is a short-term endeavor to make a new product or service. It is temporary, unique & purposive, has interrelated activities and progressively elaborated. The report outline characteristics of a project as;

1. Successful project are projects that are on time, within budget and with all features as originally specified;

2. Challenged projects are projects- which are completed, implemented, over budget, over time and with fewer features; and

3. Impaired projects are projects that are cancelled at some point during the development cycle.

I. Triple Constraint (The iron Triangle)

A project success is measured by all the parameters illustrated in Figure 2.4. Project success has and still is dominated by the conservative methods of time, cost and quality (Ogunlana, 2010). In project management time, cost and quality are the predominant parameters in assessing project realization.

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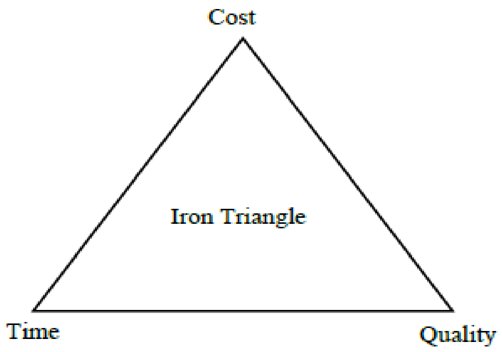

Figure 2.4 The iron triangle

Source: (Ebbesen & Hope, 2013; Lombard, 2011)

This iron triangle is used to explain the dependency between the three parameters (Ebbesen & Hope, 2013). According to this report project cost is most likely to be high when they are executed at a fast pace with high quality. However, when constructed with fast pace with little costs incurred, alternatively, it may be difficult to deliver a product of high quality. Finally, projects, which are executed using little cost, and good quality may result in time consumption. Therefore, stakeholders should endeavor to deliver the "ideal project", not compromising on high-quality project to be delivered on time, quality and within budget. Ebbesen & Hope, (2013) demonstrated the dependency between the iron triangle parameters. They considered the parameters in relation with each other, and how they indirectly affects one another.

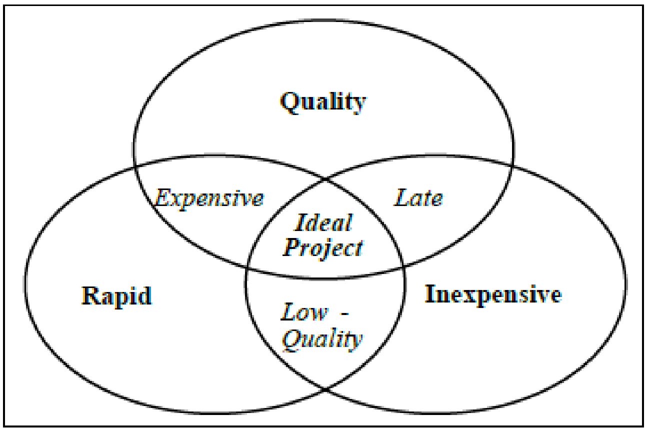

Figure 2.5 Dependence model of the iron triangle

Source: (Ebbesen & Hope, 2013; Lombard, 2011)

2.3.1 Prefabrication for Project Time Success

According to Driscoll (2013), time is money in the construction industry. He opined that construction time is one of the principal considerations in the construction industry. He further, related construction projects time with costs. He pointed out that effective time management is relevant to eliminate time and cost overruns in any construction project. Lombard (2011) conducted a study on how design factors influence time and cost for in-situ concrete construction and prefabrication projects. It was identified through interviews conducted with professional consultants in the construction industry that, prefabrication construction was more dependent on standardization and repetition when compared to conventional in-situ concrete construction.

Holla et al., (2016), comparing cast-in-situ method to the prefabrication method of construction, the latter consumes less time in the project cycle because, the prefabricated materials and elements are delivered to the site just-in-time and placed into position which reduces unnecessary handling, double handling and equipment use. This allows other activities and trades to begin work more quickly which facilitates the construction project time and is more economical with fewer disturbances for the surrounding. They further explained that cast-in-situ method of construction requires a lot of time since concrete requires minimum of 28 days to achieve 99% strength of its total strength.

According to Holla et al., (2016), in recent times, most building construction projects consider the speed of construction, tight construction schedules as basic factors, and this is where prefabrication method of construction excels. To clearly explain the cost-related advantages of prefabrication, two factors should be carefully noted:

- Design the building layout to maximize repetition of precast units.
- Design construction details to maximize the number of standardized components.

He also conclude, the duration of prefabrication in building projects studied, and were calculated through the data collected from the prefabricated manufacturers. The duration period for the completion of the projects successfully was put in three stages – the sub-structure, superstructure and finishing works. It was noted that substructure construction took the same time for cast in-situ and prefabrication. However, for the superstructure, construction was completed early with prefabrication. This is because, the walls, slabs and other elements were manufactured off site and installed on site as and when the elements were required during the time of the project.

2.3.2 Prefabrication to Save Project Cost

Cost in the construction industry remains the principal parameter (Piek, 2014) citing (Khosravi & Afshari, 2011). Notably was the fact that, cost cannot be easily measured in the construction industry. He further outlined that, construction projects cost emanates from various phases, such as the design phase, construction phase and the operation and maintenance phase also known as the life cycle cost.

For instance, Lombard (2011) conducted a theoretical example project, which he formulated in his study to demonstrate the effect of time savings during the building usage. His study revealed that, the yearly income required in order breaking even after a usage period of 30 years could be reduced by 2.67 % when the construction duration is reduced by 20%. He conducted further assessment for projects with reduced construction durations, varying construction cost and reduced maintenance cost, to observe the impact of these parameters on the life cycle cost of a project

Sivapriya and Senthamilkumar, (2016) also conduct a case study In case of cost and conclude overall cost required for constructing the building using precast concrete method is reduced by 20% when compared to conventional method. Economies are generated through reduced requirements for formwork, access scaffolding and less reliance on wet trades. Reduced on site - supervision by the main contractor is also a saving. He also show that Compared to cast in situ, the following savings can be expected: Formwork 75% less, Scaffolding 75% to 90% less and Wet concrete 90% less due to Factory production ensures increased accuracy and quality of finish and decreases weather dependency. In addition to these, he also verify that Compared with cast in situ structures, site labour is reduced by between 50% and 80% using precast. Work for following trades is reduced by between 30% and 50% depending upon finishes.

The cost of prefabrication may vary with the type and the size of construction. For instance, in small projects the cost of prefabrication increases due to the production levels. However, for bigger projects the cost may decrease significantly due to the higher levels of production. This was due to the fact that the prefabrication method of construction has an upper hand in the construction of heavy industrialized infrastructure but its implementation in the construction of individual houses has had a lot of constraints. It was also noted that, construction companies in developed countries had comparatively high labour wages and thus, they increase the capital investment in order to decrease the labour input.

The major variations for cost comparison between cast-in-place and precast occur in the cost of formwork, reinforcement, cost of workmanship, and concrete in slabs and columns.

2.3.3 Prefabrication to Promote Project Quality

According to Lombard (2011), Quality is the entirety of features and characteristics of a product, service or its entity that allow on its capacity to fulfill specified or implicit requirements. Construction quality has the ability to reduce potential time and cost savings when the quality aspects of applications in construction are overlooked. From the customer perspective, conformance to requirement and fitness of use is quality. These have an indirect impact on the time and cost of construction projects, and for that matter should be critically looked at to ensure the project success. He also defined construction quality by identifying different scopes of quality. He identified them as long and short term quality, noting the construction phase of a project as the short term quality and the operational phase of the project as the long term quality.

For instance, in Spain, the government built over 200 public school centers at Catalonia using industrialized precast expertise since the year 2000. These schools were erected in a remarkably short time quick on-site assembly, high quality product and within reasonable cost (Oriol, el at 2010). The benefits of prefabricated components in the management of construction projects has been tried and tested in so many countries so that in the management of construction projects especially when mass production is required within a specific time and quality required within an estimated budget.

It can therefore be concluded that prefabrication is economical when carefully compared to other conventional in-situ methods which are being used since 700 B.C. Prefabrication or precast is a cost and time saving construction method which ensures quality of concrete to its maximum extent.

2.4 Advantages and Disadvantages of Prefabrication

2.4.1 Advantages of Prefabrication

Civil today illustrates some advantages of precast concrete regarding cast in-situ as:

1. **Saves Construction Time:**- the risk of project delay is less because the materials are transported only for erection. The precast concrete casting can carried on simultaneously with other works on site such as earthwork, survey etc. and thus saves time.
2. **Quality Assurance: -**since precast materials are produced in the controlled environment, the key factors which regulate the quality of construction such as curing, temperature, mix design, formwork etc. can be monitored easily So, improved quality construction can be performed.
3. **Usage of Pre-stressed Concrete: -** By using pre-stressed precast, structural materials of high strength and load-bearing capacity can be achieved, which can result in greater clear span, reduced size of cross section of structural members etc.
4. **Cost-effective: -** The simplified construction process reduces the time, increases the productivity, quality and safety and thus the cost is reduced.
5. **Durability: -** Precast Concrete structure has longer service time period and minimal maintenance. The high-density Precast Concrete is more durable to acid attack, corrosion, impact, reduces surface voids and resists accumulation of dust.
6. **Aesthetics: -** As the structures are prefabricated in a controlled factory environment, several combinations of colors and textures can be used. A wide range of shapes and sizes are available to choose from with smooth finishing and thus the aesthetical value of products are increased.

7. **Safe Construction Platform:** - No raw materials have to be stocked in site for Precast Concrete construction. It reduces the requirement of traditional formworks and props, wastage; workers etc. and thus provides a safe working platform.

In addition to those, Cudney (1998) also outlined the following advantages of prefabricated concrete element compared to cast in place method of concrete construction:

- Concrete quality is better and in good finish.
- Benefit of precast flooring having long span ability thus reducing the use of formwork since it is self-supporting.
- More adaptable in harsh condition and Wastage can be recycled
- Easy for sanitary and electrical installation
- Easy for dismantling and materials can reused several times

2.4.2 Disadvantages of Prefabrication

Civil daily outlined the following dis advantages comparing to cast in place

1. **High Initial Investment: -** For installing a Precast Concrete plant, heavy and sophisticated machines are necessary which requires high initial investment. A large scale of precast construction projects must be available to ensure sufficient profit.

2. **Transportation Issue: -** The construction site maybe at a distant location from the Precast Concrete plant. In that case, the precast members must be carried to the site using trailers.

3. **Handling Difficulties:** - Proper care and precaution have to be taken for handling precast concrete. Usually, precast members are heavy and large which makes it difficult to handle without damage. Generally, portable or tower cranes are used to handle the precast members.

4. **Modification: -** Limitation In case of precast structures, it is difficult to modify the structure. For example, if a structural wall is to be dismantled for modification it will impact the overall stability of the structure.

5. **Sensitive Connection Works:** - Assembling of the precast members is one of the key points for ensuring strong structural behavior. Connections between several structural members must be supervised and done properly to ensure the intended behavior of the

connection such as simple, semi-rigid or rigid connections. Besides this, faulty connections may lead to water leakage and fail sound insulation.

In addition to these, Cudney (1998) also outlined the following disadvantages of precast concrete element compared to cast in place method of concrete construction:

- Relatively higher maintenance cost since the gap between two components needs to be sealed.
- The gap provide for leakages and needs to be repaired at regular period of time.
- The depth of the beams affects the head room and lighting.
- Since they are heavy they need large hauling equipment and heavy lifting cranes.

Table 2.1: Comparing benefits of prefabrication elements and on-site building process

Factor	**Prefabrication**	**On-site**
Quality	In a climate-controlled environment using Efficient equipment operated by well-trained people.	Uncertain weather can result in less-than expected construction.
Speed	Speedy process (up to 70% less)	Time consuming The process can be delayed by weather or Scheduling conflicts.
Cost	Greater control over manufacturing results Dramatically reduces the chance of cost overruns.	Uncontrollable variables such as weather and scheduling can increase the construction cost
Versatility	Less	More
Site space	Panels arrive on a flatbed trailer and are installed with sufficient listing plants	Bigger space is needed In addition, costly scaffolding is often necessary for installation.
Site refuse	Less waste is generated at the site.	A significant amount of waste produced and removed from the Site, which often adds to cost.

Source: (Bendapudi S.C.K, 2013)

2.5 Application of Precast Concrete Buildings

According to **Van Acker et.al.** (2001) the applications of precast buildings was categorized as below:

a. Industrial and Commercial Buildings, Parking Garages Etc.:-

Systems, using frames composed of columns and beams are still widely applied. The most prominent current changes are larger spans, lighter structures and new types of connections. A new system for industrial buildings is using load bearing sandwich walls in architectural concrete and long span lightweight TT roof units. The latter have a self-weight of 180 to 200 kg/m² and are spanning from facade to facade over up to 30 m. The system offers a more rational, economical and aesthetic construction.

b. Housing:-

Large wall panel systems combined with hollow core slab floors are still currently used for housing Projects. However, the design has become much more flexible. The formerly rigid bloc shaped realizations here now replaced by much more lively architectural designs. In the Netherlands, a new hybrid system for domestic projects has been introduced successfully in the beginning of the 1990's. The internal load bearing walls are made with large smooth silica stone blocs with accurate dimensions and tooth and groove connection. They are glued together to form the wall. The blocs are pre-cut at the factory to form the openings for windows, doors and other details. Only a slight rendering is needed to finish the walls. The precast hollow core units are supported on the walls.

c. Office buildings:-

Current trends in office buildings point towards more prefabrication, more efficiency e.g. through a flat under surface for floors without underneath beams and corbels, reduced site activity by incorporating ducts and conduits in the floor elements, and safer and faster construction. Slim floor structures offer an effective solution to reduce the total floor construction height is to support the floor elements on the bottom flange of a steel beam. This enables to realize a shallow floor in which beams and slab elements are integrated within the same depth. The FIP Commission on Prefabrication has just published Guide to Good Practice with design guidelines for "Composite floor structures". Stone is highly regarded as a cladding material or finish. Its expense can be mitigated by using thin veneers in precast concrete facade units. The system provides not only economy, but also better quality, speed of construction and higher safety than traditional in situ solutions.

d. Other types of buildings:-Stadia and grandstands are often constructed in precast concrete because of the extra short construction delays. There are numerous good examples in many countries. Last year, a large arena for ice hockey for 40,000 people was constructed in Helsinki in 6 months.

2.6 Difficulties for not Using Prefabrication

According to the McGraw Hill Construction (2011) the top most reason for present professionals not using prefabrication is that, the architect did not design it into the development. Additional top motives for present developers not using prefabrication/modularization on some projects are:

i. Development kind is not appropriate and

ii. Proprietor do not want manufactured modular components

These discoveries indicates that the use of prefabrication/modularization in some circumstances were predominantly reliant on the judgments of the owner and the architect. Their study revealed that, some of the difficulties to using modularization comprise taking to compel to a well-defined range initial in the development phase, improved conveyance and logistics necessities, and the inadequate number of suppliers of off-site manufacture, which may be similar reasons for the very low patronage of prefabrication in the study area.

Nanyam et.al. (2017) also outlined that, Adoption of precast technology is constrained by many challenges at the project level and at the industry level. Considering the challenges faced, there is a need to address these concerns for the adoption of precast technology at the sector level. Hence, the challenges are grouped into 4 categories namely:

- Standardization, Procurement, and Technological aspects
- Documentation and Design aspects
- Skill Development and human resources
- End-user perspective (acceptability and social dimensioning).

2.7 Prefabrication concrete construction practice in Ethiopia

Studies shows that there is no enough literature about the history & back ground of precast concrete components in Ethiopia, because of the reason that there is a gap for the Knowledge & skills of precast concrete elements in building projects. Still now, Precast Production Company is not distributed in our country. Prefabricated Building Parts

Production Enterprise (PBPPE) was the first precast concrete company established in 1987 with the help of the socialist country of Yugoslavia. The company was named Prefabricated Building Parts Production Enterprise (PBPPE) until September 2016 GC. But, after this time it is reorganized and reformed under the Ethiopian Construction Works Corporation (ECWC) and is named as the Building Technology and Construction Sector (BTCS) and it is also a grade one contractor. In addition to this kality precast concrete production company was working three years ago but because of shortage of demand it's not working on precast concrete rather working on precast steel materials production.

The Ethiopian Construction Works Corporation (ECWC) is a newly established public enterprise with the authorized capital of Birr 20.3billion; on December 18, 2015 based on council of Ministers Regulation No. 366/2015. The Public Enterprises Proclamation No.25/1992 governs ECWC. Its supervising authority is The Ministry of Public Enterprises and its policy-making body is the Board of the Corporation whose members the government selected from different organizations appoints. The headquarters of the corporation is located in the city of Addis Ababa, around Gured Shola.

It is head by a Chief Executive Officer (CEO). The Corporation is a result of the amalgamation of two formerly independent public enterprises, namely the Ethiopian Road Construction Corporation and the Ethiopian Water Works Construction Enterprise. While it is a recent phenomenon, which is established on December 18/2015, its history part of the history of the above-mentioned former enterprises and hence can be traced back to the late 1940s and early1950s. During the past 65 years, the operational wing of the Authority has been constructed over 21 Asphalt road projects, 45 gravel road projects, 5 airports and airstrips and 5 dams as well as mentioned almost all road networks of the country. The vision of the company is to be a worldwide competent construction company by 2026. ECWC is working having an aim of using skilled manpower and modern technology, delivering quality construction works both domestically and overseas, assembling construction machineries, and equipment, manufacturing spare parts as well as acquiring, owning and administering dams constructed by the government, collecting charges from the beneficiaries of such dams and expanding such development activities. ECWC is working with a core value of Quality First, Team Work. The Area of Business for ECWC are Water Infrastructure Construction, Transport Infrastructure

Construction, Buildings Infrastructure Construction and Irrigation-Dams-Deep & Water wells.

Currently, BTCS construct three-governmental prefabricated buildings in Addis Ababa through assembling of components, such as Information and communication Technology Incubation center (ICTIC) around Gorro, Addis Ababa Melese Zenawi Leader Ship Academy (AAMZLA), which is located around Ayat and Kotebe Metropolitan University Administration Office (KMUAO). The company also constructs the head office of governmental organizations in Addis Ababa by composite methods of construction. Ethiopian Revenue and Custom Authority (ERCA) and Ethiopian Science and Technology Minister (ESTM) etc. are also constructed by BTCS.

Generally the increasing price of building construction projects, primarily due to increasing prices of the building materials, and construction delaines, conversely, calls for in expensive & faster methods of construction. The use of such methods of construction, especially in a Developing country like, Ethiopia where there is a limited source of building materials might be proved economical .One of such cheaper & faster method of construction is the use of prefabricated concrete components.

3. RESEARCH METHODOLOGY

3.1 Research Area

Every research undertaken requires the selection of study location that exhibits the phenomenon to be investigated. Prefabrication method of construction was rarely adopted for the management of construction works in the building industry. Despite the enormous benefits of prefabrication method of construction developing countries like Ethiopia yet to realize this and fully enjoy the benefits. This study particularly assess the advantages gained by prefabrication concrete in building construction regarding cast in place concrete building construction around **Mekelle** city which is located in Tigray region, Ethiopia.

Mekelle formerly the capital of Enderta awraja in Tigray, is today the capital city of Tigray National Regional state. It is located around 780 kilometers (480 mi) north of the Ethiopian capital city Addis Ababa, with an elevation of 2,254 meters (7,395 ft.) above sea level. Administratively, Mekelle is considered as Special Zone, which is divided into seven sub-cities. Mekelle is the economic, cultural, and political hub of northern Ethiopia.

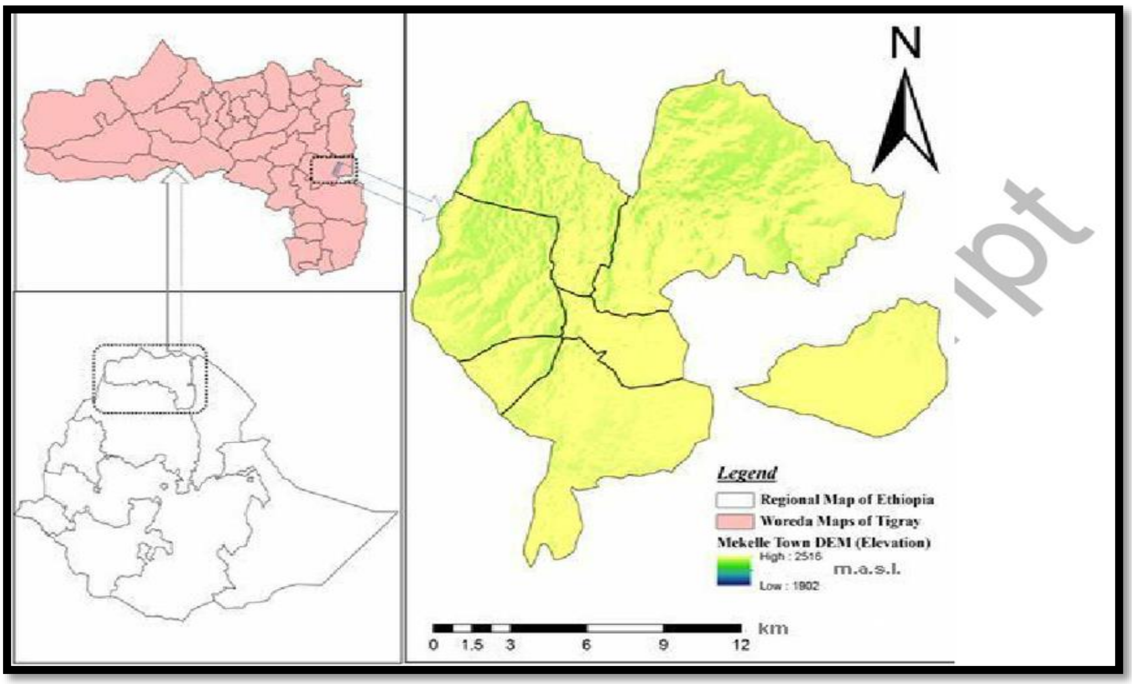

Figure 3.1 study area google map (Mekelle city)

3.2 Research Design

In this study the research design adopted was descriptive method, this was considered appropriate due to the fact that the study involved systematic collection and presentation of data to give a clear picture of the situation. However, both quantitative and qualitative approaches were applied because most authorities in research method admit that the two distinct process (quantitative and qualitative) can co-exist, but the most significant differences is the method in which each convention treats data. Conclusion and recommendations were drawn based on the data analyzed from the questionnaires, interviews and site observations and literatures.

3.3 Study Variables

Dependent variables

- ✓ Effectiveness of precast and cast in-situ concrete in building construction

Independent variables;

- ➢ Stakeholder awareness
- ➢ Time related benefits
- ➢ Cost related benefits
- ➢ Quality related benefits

3.4 Study Period

This research started on April 2019 and ended on January 2020.

3.5 Sampling Method and Sample Size

One method to decide sample size is the purposive sampling method; this method was selected for this study. This sampling technique were chosen because it is the most effective of exploring the heterogeneous data since data required are anthropological, and the sources of data collected were of more meaning and of high benefit to the study, the data collected were of more intuitive nature and the actual population could not ascertained from authoritative sources.

In this research, the selection of samples from the total population were non-probabilistic sampling and selection of stakeholders above was purposive. The selection of individual contractors, consultants and clients respondents who made up the sample size were selected by their knowhow and experience in building construction industry specially in prefabricated concrete building construction by applying a pilot survey before by a means of interview.

3.6 Source of Data

The study made use of primary and secondary source of data. Primary sources of data collected from interviews, questionnaire and observations; these was specific tools used according to the various categories of respondents at the time. Secondary data sourced from existing published data concerning the research topic from textbooks, journals, internet and magazines.

3.7 Data Collection Instruments

Generally, there are various instruments for collecting data in social research, however, for the purpose of this study, interviews (structured interview), field observations and questionnaires were the primary instruments used for data collection as indicated below.

3.7.1 Observation

Observation provides evidence that do not depend on verbal behavior and enables the researcher to critically observe the phenomenon under study directly. The purpose was to facilitate a deeper understanding of issues and cross checking of responses considered being inconsistent to what was observed. This process helped to improve the validity of the findings. For this study, the observation starts from the ECWC precast concrete Company on how the materials produced and continue to construction sites.

3.7.2 Questionnaires and Interviews

A questionnaire is a written instrument that contains a series of questions or statements that attempt to collect information on a particular topic, in this case regarding the effectiveness of prefabricated concrete. Structured, closed and open-ended questionnaires administered to a cross section of respondents to solicit their information on the topic. An interview were the additional data for analyzing and held on to the stakeholders of the concrete building construction.

3.8 Data Analysis

Two types of data namely; qualitative and quantitative were collected and analyzed accordingly. Despite the nature of the data collected, Fellows and suggested that were appropriate to start the analysis by examining the raw data using broader understanding. This indeed includes a review of theory and literature, which leads to problem identification, and comparison of the methods of concrete construction in building projects. The data analyzed on this research focused on three major specific objectives aimed at answering three research questions.

The Likert scale data was analyzed using relative importance index (RII) method. RII method was used herein to ordinals arranged variables in terms of importance and agreement to determine professionals ‘perceptions of the relative importance of the identified advantages. According to (Cheung and Suen, 2004) the RII was computed as -

$$RII = \frac{\sum W}{N*A}$$

Where W is the weight given to each factor by the respondents and ranges from 1 to 5 or 1-3

A – The highest weight = 5 or 3 in this case;

N – The total number of respondents

The data collected from respondents, ECWC was analyzed by qualitative and quantitative method.

3.8.1 Quantitative Analysis

Quantitative analysis involves mathematical operations, which quantifies the results into numerical values. These involves statistical analysis such as, descriptive statistics. Descriptive refers to the description or summary of data gathered for a group of individual unit of analysis (Kothari, 2004). Quantitative data extracted from open, close-ended questionnaires encoded using tables, charts, and graphs and the results interpreted carefully.

3.8.2 Qualitative Analysis

Qualitative analysis involves different kinds of personal experiences and theoretical opinions. This form of analysis measures in-depth individual interviews and group interviews (WeIman et al., 2006). The qualitative data for this study calculated in Microsoft Excel and analyzed using relative importance index (RII).

3.9 Ethical Consideration

A number of ethical considerations addressed in the case of the research, these included assurance of anonymity and confidentiality of personal information. The nature, purpose and procedure of the study explained to the respondents and they could be aware that they were free to refuse to answer any question or drop out of the study at any time and would not affect them. Permission to conduct this research could sought for stakeholders before the actual work began in order to ensure access and acceptance.

Access to construction sites and acceptance in obtaining permission to carry out research in a construction sites, consultant office or organizations is relevant.

4. RESULT AND DISCUSSION

4.1 Introduction

This chapter comprises, the analysis of questionnaires, interviews, and observations made in the course of the study. A cross-section of building contractors, architectural and engineering consultants and clients or developers who are key stakeholders in the construction industry within the Mekelle city were engaged in the data collection process as respondents.

As far as this chapter was concerned ninety: (90) questionnaires were administered and out of the total number, seventy eight (78) were received representing 86.67% of total were returned questionnaires. Histograms, Tables, pie charts and percentages below was used to present the data collected. The data was subjected to rigorous statistical analysis after respondents reacted to all the items contained in the questionnaire alongside interviews, observations exercise concerning the research topic.

4.2 Demographic Data

4.2.1 Type of Respondents

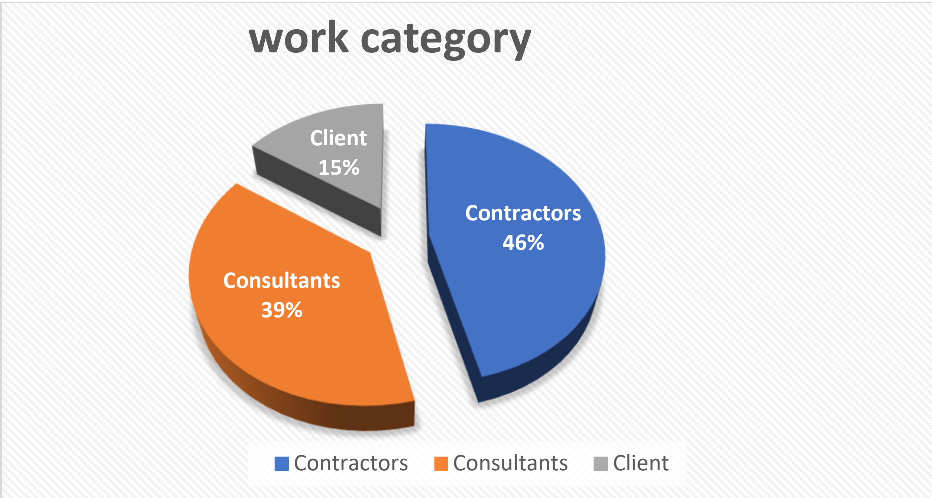

Figure 4.1: respondents work category

Figure 4.1 shows the number of respondents with their percentages from the following category: contractors, architectural/engineering consultants and clients. From those 36 out of 78 (representing 46.15%) of the respondents were contractors, 30 out of 78 respondents were architectural/engineering (representing 38.46%), and 12 respondents were clients or developers or government agency (representing 15.38%).

4.2.2 Level Of Education

Table 4.1: Respondent's level of education

Variable	Category	Respondent number	Percentage
Level of education	None	-	-
	Diploma	6	7.7%
	Degree	60	77%
	Masters	12	15.3%

Table 4.1 depicts the level of education of respondents, 15.3% of the respondents have second degree (masters), 77% of the respondents have first degree and 7.7% of them was college graduates (diploma). Majority of the respondents were educated (first degree) and had a good understanding of the questionnaire that they were required to respond.

4.2.3 Years of Working Experience

Table 4.2: Respondents work experience

Variable	Category	Frequency	Percentage
Work experience	0-5 years	14	17.95%
	6-10 years	36	46.15%
	Greater than 10 years	28	35.9%
	Total	78	100%

Table 4.2 shows the years of working experience of respondents in the construction industry specifically in building construction, 14 respondents (representing 18%) have working experience between zero to five years. 36 respondents out of 78 respondents have 6-10 years working experience (representing 46%). In addition, 28 of the respondents have greater than 10 years working experience (representing 36%), This implies that majority of the respondents were quite experienced in the construction industry as far as responding to this questionnaire is concerned.

4.3 Form of Construction

Many literatures categorize the form of concrete building construction in to three namely conventional (cast in-situ), precast and combined of the two (precast and in-situ)

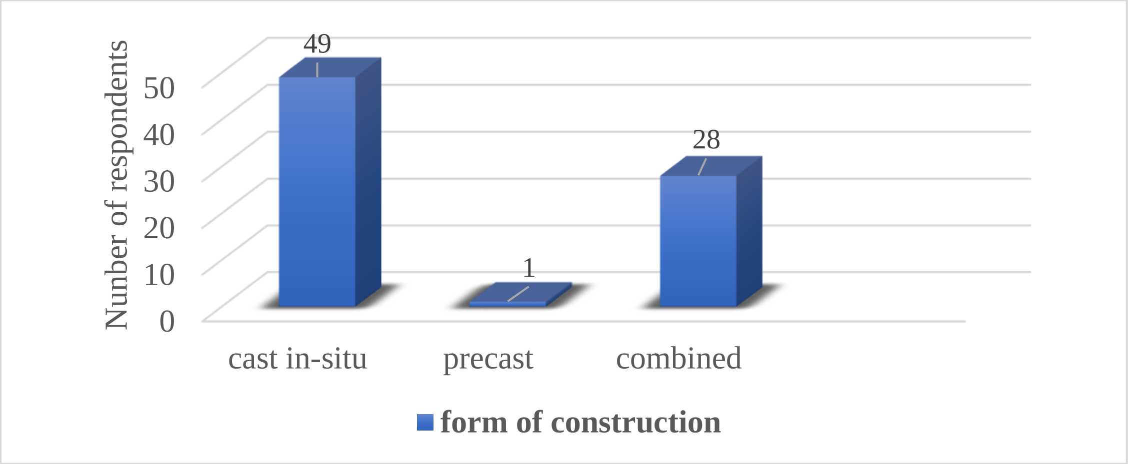

Figure 4.2: form of construction used by respondents

figure 4.2 shows the form of construction that the respondents of this study were using such that 49 respondents use cast in-situ or conventional method of construction, 28 respondents use combined method of concrete building construction. The result indicates that most of the respondents use conventional method of construction and their reason to select this type of construction was indicated next.

Figure 4.3: Precast concrete building construction

4.3.1 Reason of Respondents to Select the Form of Construction

Table 4.3 illustrates the reason why most of the respondents use cast in-situ form of construction. 42 respondents out of 78 reasoned because Precast production company was not available locally, high transportation cost and 35 respondents reasoned In-situ is easy for any irregular design than precast. One of my respondent, which were using precast concrete states that precast concrete method, provides the requirements of "ideal project" which are better quality, saves construction time and reduced budget.

Table 4.3: why respondents select precast or cast in-situ

Reason	Frequency	Percentage
In-situ is easy for any irregular design but not precast	35	44.87%
Precast production company is not available locally, high transportation cost	42	53.85%
Precast relatively offer short time and low cost and have better quality (ideal project requirement)	1	1.28%
Total	78	100%

In addition to this The data from interview indicates Some stakeholders use combined of precast and in-situ method in order to get the advantage of shorter construction time and lower construction cost than in-situ method.

BABU et al. 2013, identify the advantages of prefabrication concrete as, prefabricated concrete having a special qualities of fire protection, high thermal capability, durability and acoustic insulation of any climatic conditions. He also state using this prefabricated technology has been proven architectural flexibility, superior quality, less labor requirement, ease of construction at site, less wastage of natural resources, low maintenance good solution for work safety. As the interview data stated, prefabrication concrete have great role in achieving green building goals such as:

- **Waste minimization**: during the production of elements in prefab industry wastes can reused
- **Materials**: locally available materials may use like aggregate and sand and decrease the use of construction materials comparing to in-situ.
- **Tight envelope**: Large prefabricated panels have fewer joints and sealed on site.

- **Site Impact:** The lack of scaffolding reduced the site impact and increase safety for workers.

4.3.2 Time, Cost, Quality and Method of Construction Relationship

Table 4.4: form of construction and time, cost and quality relationship

Factor	Cast in-situ			
	Less	medium	More	RII
Time	13	35	30	0.74
Cost	8	37	33	0.77
Quality	6	18	54	0.87
Factor	Precast			
	Less	Medium	More	RII
Time	78	0	0	0.33
Cost	12	18	48	0.82
Quality	15	39	24	0.71
Factor	Combined			
	Less	Medium	More	RII
Time	12	54	10	0.64
Cost	0	30	46	0.85
Quality	0	36	42	0.85

Table 4.4 indicates the perception of the respondents for these form of construction listed above in terms of cost, time offered during construction and quality of products. Their result indicates that for cast in-situ the time offered for construction have RII = 0.74, overall cost have a value of RII=0.77, and the quality of structures with RII = 0.87. The result of the professionals for precast concrete shows time have an RII value of 0.33, cost RII=0.82 and quality of the products have RII=0.71 and the result of the stakeholders for combined form of construction gets an RII =0.64 for time, RII=0.85 for cost and quality.

The result above indicates that all of the respondents agreed with the idea precast concrete construction offer less time for construction with RII=0.33 but they state that precast have high cost than cast in-situ with RII of 0.82 and 0.77 respectively. In terms of quality, the respondents agreed prefabrication concrete structures have better quality. As stated by (BABU et al. 2013) Off-site fabrication provides effective constructional advantages in terms of time, cost and quality such as:

Table 4.5: Time, cost and quality effectiveness of prefabrication

Factor	Prefabrication	in-site
Speed	Speedy process (up to 70% less)	Time consuming. The process can be delayed by weather or scheduling conflicts.
Cost	Greater control over manufacturing results dramatically reduces the chance of cost overruns.	Uncontrollable variables such as weather and scheduling can increase the construction cost
Quality	In a climate-controlled environment using efficient equipment operated by well-trained people.	Uncertain weather can result in less-than expected construction.

Same to (BABU et al. 2013) majority of my respondents also agree with the idea of precast concrete building construction offer less time for construction and have high quality but may need high initial investment.

4.4 Building Construction Stakeholder's Awareness

Table 4.6: Stakeholder's awareness about precast concrete construction

	Respondents awareness about precast concrete			
	Not aware	Less aware	Aware	Total
Frequency	-	47	31	78
Percentage	-	60%	40%	100%

Table 4.6 indicates the awareness of the stakeholders (contractors, consultants and project owners) about precast concrete in building construction and 60% of the respondents have less awareness, 40% of them are aware of what precast concrete is. Pasquire et al. (2005) stated that, data of precast concrete projects are generally undocumented and that decisions to use precast concrete elements are not based on well-defined information. He

also verified there is very little, if any, quantitative comparisons that project teams (client, engineers, and contractor) can apply to consider precast concrete as option for the construction of buildings. That is why the stakeholder's awareness is not much. As we have seen above most of the respondents have less awareness about the precast concrete, this paper try to create awareness about precast construction through discussing the advantages of precast concrete over cast in-situ.

4.4.1 Stakeholders Perception on Cast In-Situ and Precast Concrete Method

Table 4.7: stakeholder's perspective on cast in-situ and precast concrete

Factors	Cast In-Situ		Precast		Combined	
	RII	Rank	RII	Rank	RII	Rank
Easy for installation and sanitary	0.67	2	0.8	6	0.57	5
Reduce wastage of materials	0.48	5	0.84	5	0.53	10
Easy for demolition	0.29	9	0.8	6	0.35	12
Less health and safety problem	0.43	7	0.74	11	0.64	2
Leakage problem	0.52	4	0.76	10	0.56	7
Limited site space	0.33	8	0.77	9	0.57	5
Higher initial cost	0.26	10	0.97	2	0.59	4
More adaptable to harsh condition	0.25	11	0.94	3	0.52	11
High aesthetic value	0.74	1	0.9	4	0.56	7
Reduced construction cost	0.58	3	0.59	12	0.56	7
Reduced time for construction	0.24	12	0.98	1	0.64	2
Better quality	0.47	6	0.8	6	0.73	1

RII- Relative Importance Index

The table above describes the level of agreement on the comparative study of the three method of construction regarding different criteria's with leveling numbers 1= strongly disagree, 2=disagree, 3=neutral, 4=agree and 5= strongly agree.

The rank of RII indicates that cast in-situ have High aesthetic value, Easy for installation and sanitary, Reduced construction cost, have a Leakage problem, Reduce wastage of materials, Better quality, Less health and safety problem, Limited site space, Easy for demolition, Higher initial cost, More adaptable to harsh condition & Reduced time for construction with RII value of 0.74,0.67,0.58,0.52,0.48,0.47,0.43,0.33,0.29,0.26,0.25 & 0.24 respectively.

The result of the respondents regarding precast concrete was ranked out as: Reduced time for construction, Higher initial cost, More adaptable to harsh condition, High aesthetic value, Reduce wastage of materials, Easy for installation and sanitary, Easy for demolition, Better quality, Limited site space, Leakage problem, Less health and safety problem & Reduced construction cost with RII value of 0.98, 0.97, 0.94, 0.9, 0.84, 0.8, 0.77, 0.76, 0.74 & 0.59 respectively. From the result above, the RII value of precast is greater than cast in-situ stating precast concrete method is effective on the criteria's list out above. The result for combined form of construction was also slightly greater than cast in-situ construction meaning combined form was better than cast in place regarding the criteria stated. As quantified above precast concrete construction have different advantages over cast in-situ but many people have not aware and have miss-understanding about the advantages of precast concrete construction.

4.5 Time and Cost Related Benefits of Precast and Cast In-Situ

4.5.1 Time Related Benefits

All of the respondent's state that it was possible to reduce the time offer to construct building projects using precast concrete comparing to conventional (cast in-situ).

Table 4.8: Time related effectiveness of precast

Factors	RII	Rank
Reduce time to erect and dismantle scaffolding and formworks	0.9	1
Reduce time to cure concrete	0.89	2
Reduce time to plastering and finishing's	0.85	3
Time to mix concrete ingredients	0.83	4

Table 4.8 shows time related benefits of precast concrete than cast in-situ concrete in building projects. From the total, most of the respondents agreed it was possible to reduce time to erect and remove formwork and scaffolding (RII=0.9) and time to cure the concrete until it gets maximum strength (RII=0.89). The level of agreement for the idea using precast possible to reduce plastering and finishing works have a value of RII=0.85and some respondents agreed to reduce time offer for mixing concrete ingredients (RII=0.83).

Holla et al., (2016), noted that substructure construction took the same time for cast in-situ and prefabrication. However, for the superstructure, construction was completed early with prefabrication. This is because, the walls, slabs and other elements were manufactured off site and installed on site as and when the elements were required during the time of the project.

I. Project Schedule Status

Table 4.9: Time status of respondent's project

Project status	Result in number	Result in percentage
Ahead of schedule	12	15.4%
On schedule	18	23.1%
Delayed	48	61.5%
Total	78	100%

The table above indicate that the status of the projects of the respondents and 61.5% of the projects were delayed their status, 15.4% ahead schedule and 23% on schedule.

As illustrated above, most of the projects have a time delay in their schedule, and huge resources of the country were wasting due to not translating to service and one of the main reason for this delay was the form of construction used. There are different methods of concreting one of which was the conventional method of concreting denominated like cast in-situ that was mostly used for the construction. This was the oldest method of concreting and used for many years in the construction industry. Cast-in-situ is the conventional method of concreting. In this method, concrete was prepared on site and poured in to formwork then cured. It often requires more work and even takes more time until it gets maximum strength. Precast construction techniques requires less time for onsite construction as compared to Cast-in- situ concrete method, because the prepared materials are transported to site and can be directly lifted and placed on the desired position.

II. Main Causes of Delay

Table 4.10– indicates level of agreement for the main causes of time delay that which raised by the respondents in the building construction both for precast concrete and precast method of construction.

Table 4.10: main causes of delay in the building projects

Cause for delay	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	RII	Rank
Delivery of materials	0	0	0	42	36	0.89	1
Design error	0	3	0	39	36	0.88	2
Form of construction Used	0	0	8	38	32	0.86	3
Remedial works	0	15	0	50	13	0.76	4
Insufficient plant and Equipment	3	24	0	41	10	0.68	5

The table above depicts the level of agreements of the respondents and delivery of materials were the major cause of delay and ranked as first with RII value of 0.89, design error R=0.88. Form of construction used was ranked third with RII value 0.86 and remedial works and insufficient plant and equipment as fourth and fifth with RII=0.76 and 0.68 respectively. As stated in the literature review the method that was used to construct building projects affect the time schedule of projects and was one criteria raised by the respondents as one reason for delay of projects. Majority of the building construction industry in our country depends in conventional or cast in-situ concrete method and have time delay in their schedule.

III. Time Comparison

As stated by the respondents there are many reasons for delay but the major cause was the method of construction used. Generally, in precast method, Construction time was reduced and buildings completed sooner, allowing an earlier return of the capital invested and Time spent due to bad weather or hazardous environments at the construction site was minimized.

The table below indicates that the total time needed to construct a building using both precast and cast in-situ concrete materials. The production and erection time were get from the precast concrete factory and is per pcs and in order to compare with cast in-situ, conversion to per cubic meter is necessary. As specified by the respondents the time offered using precast concrete is slightly lower**(62.9%)** than that of cast in-place because in precast method time was needed only for production of the material and for erection because the materials can delivered just-in-time. However, during cast in-situ the process includes time to erect and dismantle formwork, mix ingredients, place concrete and curing until it gets maximum strength. The duration includes time to rebar placing, formwork installation and concreting.

Table 4.11: per cubic meter production and construction time required in precast and in-situ concrete

	Time needed for production and erection of precast					Total time offered	
Type	Size (m)	Production time/pcs	Production time/m^3	Erection time/pcs	Erection time/ m^3	Total time for precast	Cast in-situ
Column	0.3*0.3*3.5	12h	38.09h	¼ h	0.794h	38.884h	2.5d
Beam	0.22*0.17*4.2	4h	25.46h	¼ h	1.59h	27.05h	2d
Slab	0.22*4.2*4.2	14h	3.6h	1h	0.26h	3.86h	3d
Stair	2.9*1.25*0.20	24h	33.1h	½ h	0.69h	33.79h	3.5d
Wall	3.8*3.38*0.25	10h	3.11h	½ h	0.156h	3.266h	1d
Average			**20.672h**		**0.6972h**	**21.3692h**	**2.4d**

As stated by Holla et.al (2016), Compared to cast-in-situ method, the precast method consumes less time because the prepared materials and elements are delivered just in time and placed on site, which reduces unnecessary handling and equipment use. This allows other trades to begin work more quickly which speeds up the construction time and was more economical with fewer disturbances for the surrounding. Cast-in-situ method of concreting requires lots of time because concrete requires minimum 28 days to achieve 99% strength of its total strength.

The duration of a pre-casted concrete were calculated through the data collected from the precast manufacturers. The duration period for the completion of the project was categorized into three stages- sub-structure, super structure and finishing works. Where sub structure took the same time for cast in situ and pre cast but the super structure was finished quickly with pre cast, because the walls, columns, beams, stairs and slabs are produced off site and installed on site during the time of the project. In addition to this, precast structures have smooth finishing surface may bring to no need of finishing works.

Holla, et.al,(2016), calculates the time required for building concrete construction both for precast and cast in-situ and states the total duration for a double story residential building with prefab technology was 65 days while with the conventional method was 128 days which is 49.2% lesser. Dineshkumar (2015) also calculate the time required for double story residential building stating the prefabricated construction was easy to work and reduces the project duration, reduced by 63 days (50.78%) when compared to the conventional. He states that this reduction in time is the main advantages for prefabricated construction and also it helps when there is labour shortage. Because of survey we had known that the prefab construction have more advantages and procurement in industrialized, heavy infrastructures. Same to that the average production time required for precast concrete was 62.9% lesser than that of conventional or cast in place concrete construction for this study.

4.5.2 Cost-Related Benefits

The data from the questionnaire collected from building construction stakeholders indicates that 66 respondents (84.6%) agreed that the overall cost of building construction can be reduced using precast building components instead of cast in-situ and the rest 12 respondents have an idea of precast concrete have higher cost than cast in-situ.

As shown by Respondents data above, Vyas (2015) also verify the major cost related advantages as precast concrete method requires less material quantity i.e.it requires less concrete, cement and steel as it were factory made advanced mix designs and better vibrations are used. Less quantity of concrete were used in hollow core slabs. No formwork was required on site for precast concrete method. As no need for storage of materials and formwork, precast concrete method is very useful in small sized construction site with less storage space. He also state that the Number of labours is less in precast concrete method as compared to cast-in-situ method because there is no actual work on site in precast concrete as compared to cast-in-situ concrete method. As quantity of materials is less, wastage is also less in precast concrete method.

During precast concrete, fabrication unit can be located where skilled labour is readily available and costs of labour, power, materials, space and overheads are lower. However, in conventional construction, construction cost depends upon location, climatic condition & availability of material & Manpower. Studies show that Reducing cost and time were major anxieties for both consumers and manufactures in the building industry. When compared to conventional construction methods, the prefabricated construction system provides significant reductions in both cost and time. In a prefabricated construction system, the phases of site preparation and construction of the modules can be run simultaneously, while in conventional construction, the construction phase happens after the site preparation phase. With construction phase activities occurring at the same time as the prefabricated construction, great reductions in construction time occur, when compared to conventional construction practices.

However, pre-project planning is quite intensive for prefabricated construction systems, as their design has different complexities from conventional design. For example, features such as when modules transported to the final project site, placed on the foundation, and joined to form the building need to be take into account in the design phase. This requires more engineers, quality controllers and skilled labourers. These requirements will increase the cost and duration of the design phase, but they reduce the cost and time of the on-site construction phase significantly in prefabricated construction compared to conventional construction.

As a conclusion, can reduce the cost of formwork, scaffolding, labour and wastage of materials using precast concrete construction instead of cast in-situ. In addition to this since precast materials was produced in factory then transported to site for erection it can save the time to get maximum strength and to erect and install temporary works and indirectly if reducing time to construct then the building put in service and possible to reduce unnecessary claims by contractor.

I. Types of Costs Reduced

The table below indicates the idea of respondent for the question what Types of cost that can be reduced using precast concrete building construction instead of conventional concrete construction. In the precast method, ready-made components are used, so the need for formwork, shuttering and scaffolding was greatly reduced. However, in conventional construction, building components constructed at site requiring formwork, shuttering and scaffolding.

Table 4.12: Types of cost that can be reduced using precast concrete

Type of cost that can be reduced	**RII**	**Rank**
Labour cost	0.96	1
Cost of formwork	0.95	2
Scaffolding cost	0.93	3
Risk cost	0.84	4
Finishing cost	0.83	5
Concrete cost	0.81	6
Maintenance cost	0.77	7
Reinforcement bar cost	0.69	8

Table 4.12 indicates the level of agreements of the respondents on the types of costs reduced using prefabricated concrete instead of cast in-situ in building construction projects. the RII value given by the respondents on the labour cost can be reduced is 0.96, cost for formwork & scaffolding 0.95, 0.93 for risk cost, finishing cost, concrete cost, maintenance cost and rebar cost were 0.84, 0.83, 0.81, 0.77 and 0.69 respectively.

As stated by respondents, it was possible to reduce the labour cost since cranes erect precast materials with a higher productivity than labours. In addition to this cost of temporary works like formwork and scaffolding can reduced because precast concrete components were produced in controlled surface. It can be reduced the cost for finishing works like plastering because precast materials have smooth finishing surface and cost for risk because construction materials like sand aggregate and formworks do not congest the working site. However, since precast concrete building components have heavy weight they need large cranes for erection and this may become additional cost.

In prefabricated construction, Self-supporting ready-made components are used so, the need for formwork, shuttering and scaffoldings can be greatly reduced. Because of all savings and efficiency in material consumption and the methods of construction, which was carried out in a plant, and because of the expertise of the various trades involved with a project in an environmentally controlled situation prefabricated homes tends to be more cost-effective than a conventionally built house. Holla, et.al, (2016), depicts that precast concrete construction uses 20% less concrete, 30% less steel, 50% less labor, and 50% less wastage than cast in-situ during construction.

II. Unit Cost Comparison

Table 4.13: Cost and time offered for production of precast concrete in building construction

Material type	Unit	Size(m)	Cost per unit(birr)	Production time per unit	Erection time per unit	Transportation cost per km	Equipment cost per hr.
Column	Pcs	0.3*0.3*3.5	4,410	12h	¼ h	2.468birr/ km	1450birr
Beam	Pcs	0.22*0.17*4.2	1,335.18	4h	¼ h		
Slab	Pcs	0.22*4.2*4.2	25,000	14h	1h		
Stair	Pcs	2.9*1.25*0.2	6,000	24h	½ h		
Shear wall	Pcs	3.8*3.38*0.25	11,000	10h	½ h		

The table above indicates the precast concrete member production cost, production time, transportation and equipment cost per pcs gotten from ECWC (Ethiopian construction Works Corporation). The result above was in pcs so in order to compare with the cost of cast in-situ conversion to per cubic meter is necessary by crisscross method and transportation plus erection cost were added and the result summarizes as following table.

The cost of the conventional construction was calculated through the data collected from conventional construction company, for this study taken from the Tigray bureau construction office, which help to find the cost of the total project.

Table 4.14: Production cost of precast and cast in-situ concrete

Type	Unit	Cost of precast concrete/unit (birr/ M^3)	Cost of cast in-situ concrete/unit (birr)			
			Concrete cost	Formwork cost	Re-bar cost/unit	Total (birr/ M^3)
Column	M^3	14,000	2,310.23	934.62	11,539.5	14,784.35
Beam	M^3	8,500	2,310.23	934.62	8,099.7	11,344.55
Slab	M^3	6,441.9	2,390.30	1,279.2	4,615.8	8,285.30
Stair	M^3	8,275.8	2,496.94	1,279.2	4,615.8	8,391.94
Wall	M^3	3,425.7	2,496.94	934.62	4,615.8	8,047.36
Average	M^3	**8,128.68**				**9,343.71**
			Indirect cost=direct cost + overhead cost (20%) + profit (15%) = DC*1.35			**12,614**

Since precast concrete members was produced at controlled environment, or at precast factory, a large hauling equipment like trailer was necessary in order to transport to construction site and then the erection process will be held on using cranes. In case of prefabricated structures, cost can analyzed at the stage of design itself and therefore chances of fluctuation of cost was very less. However, the construction cost of conventional structure depends upon time and market fluctuations. The cost per cubic meter for erection and transportation looks like as follow.

Table 4.15: transportation and erection cost of precast concrete members

Transportation cost per cubic meter				Erection cost		
Item	Km	Birr/km/m3	Birr/m3	Birr/hr.	Time required/m3	Birr/m3
Column	778	2.468	1920	1450	47.6 min	1128.58
Beam				1450	1hr 35 min	2295.83
Slab				1450	15.46	373.62
Stair				1450	41.37	999.77
Wall				1450	8.31	200.825

There was no precast concrete factory in my study area (Mekelle), the only precast concrete factory in Ethiopia was located in capital city Addis Ababa and its far apart from Mekelle. Transportation cost per cubic meter for all member is equal which 2.468 birr/km for the trailer truck. The rental cost for crane machinery, which was used, for erection were 1450 birr/hr. however, the productivity of the crane for the precast members per pcs was not equal due to their size and complexity. Including the transportation and erection cost, total cost of the structure is summarized in the following table:

Table 4.16: Total cost comparison of precast and cast in-situ concrete

Type	Unit	Cost of precast concrete/m^3	Transportation cost per m3	erection cost per m^3	Total precast concrete cost/m^3	Cost of cast in-situ concrete/unit (birr/m^3)
Column	M^3	14000	1920	1128.58	17078.58	14784.35
Beam	M^3	8500	1920	2295.83	12715.83	11344.55
Slab	M^3	6441.9	1920	373.62	8935.52	8285.30
Stair	M^3	8275.8	1920	999.77	11195.57	8391.94
Wall	M^3	3425.7	1920	200.825	5546.525	8047.36
Average	M^3				**11,094.40**	**12,614.00**

The result in the table above indicates that per unit total cost for precast and cast in situ concrete in building construction and cost of formwork and concrete includes the labour cost needed for the specified work type. As Sujon (2019) stated the volume of rebar for every cubic meter of concrete and the volume of concrete differ with the type of structural member for example slab: 0.5-1.5% of concrete volume

Beam: 1.5-2% of concrete volume

Column: 2-3% of concrete volume

And the volume of reinforcement bar $= \left[\frac{\text{concrete volume} * 7850}{100*1} \right]$

For slab = 1*7850/100 = 78.5 Kg/ m^3

For beam = 1.75*7850/100 = 137.75 kg/ m^3

For column = 2.5 *7850/100 =196.25 kg/ m^3

NB: 7850 is the weight of rebar required per m^3 concrete for 100% concrete volume

The recent cost of reinforcement bar per kg is 58.8 birr and the total cost per cubic meter could be the multiplication of unit cost and the total Reinforcement volume per unit. As many authors indicated the average formwork area required for one cubic meter of concrete 6sqm/cum), such that for one cubic meter of concrete 6m^2 of formwork was needed. Then the formwork required for one cubic meter of concrete equals six times unit cost, which is 6*231.2 =1279.2 birr/m^3 for suspended slab and 6*155.77 =934.62 birr/m^3 for beam column and shear wall.

The result in Table 16 indicates that the total cost per cubic meter needed to construct a building using precast concrete was lower than that of cast in-situ, which was **11,094.40** birr/m^3 for precast and **12,614.00** birr/m^3 for cast in-situ we can conclude that prefabrication method is less costly than cast in-situ. Lombard (2011) states the cost of prefabrication vary with the type and the size of construction. For instance, in small projects the cost of prefabrication increases due to the production levels. However, for bigger projects the cost decrease significantly due to the higher levels of production. Dineshkumar,(2015) depicts The prefab construction for individual double story residential building cost is 13% more than the conventional construction. He state that this is main drawback for prefab construction which is not economical to construct in this case. Opposing to this idea, Sivapriya and Senthamilkumar,(2016) clearly states that the direct cost required for precast construction is very less (20%) in comparing to cast – in – situ concrete constructions. This can be achieved when the production unit is very near the site, repetitions of form of buildings indirectly demands to use the same mold repeatedly, which in turn reduces the cost of the building.

Holla, et.al, (2016), shows, precast concrete solutions can help to reduce the waste generated on site by up to 50% of a construction building compared to Cast-in situ method. He also verify that the design system, which can be implemented by the manufacturing company, is tridimensional modeling software that helps maintain the interface between the different construction elements.

Supporting Sivapriya and Senthamilkumar, (2016) idea, the result of this study indicates that the total cost of prefabrication concrete was 12% lesser than cast in-situ concrete.

4.6 Quality Related Benefits of Precast and Cast In-Situ

As stated by the construction stakeholders during an interview, Quality control was a primary part of precast construction and competent quality control is most significant in the process making of precast components in every project. The quality control system was implemented in precast industrial units. As stated by Vyas (2015), Water cement ratio can be properly adopted in precast concrete than in cast-in-situ concrete, which can lead to better quality control. In the cast-in-situ method, concrete is prepared on the site, which can be affected by weather condition. He also verify that Plaster requirement is also very less in precast concrete as product have better finish than cast-in-situ concrete method. Quality increases due to the controlled conditions under which construction is accomplished. The quality workmanship on site is variable factor however, in precast industrial units it can eliminated due to consistency in production of precast elements. As stated by Vyas (2015), there is no grout loss from badly fitted formwork, which can lead poor quality in concrete.

4.6.1 Remedial Works

The table below indicates the result of respondents regarding the frequency of remedial works that can happen in their day-to-day activity.

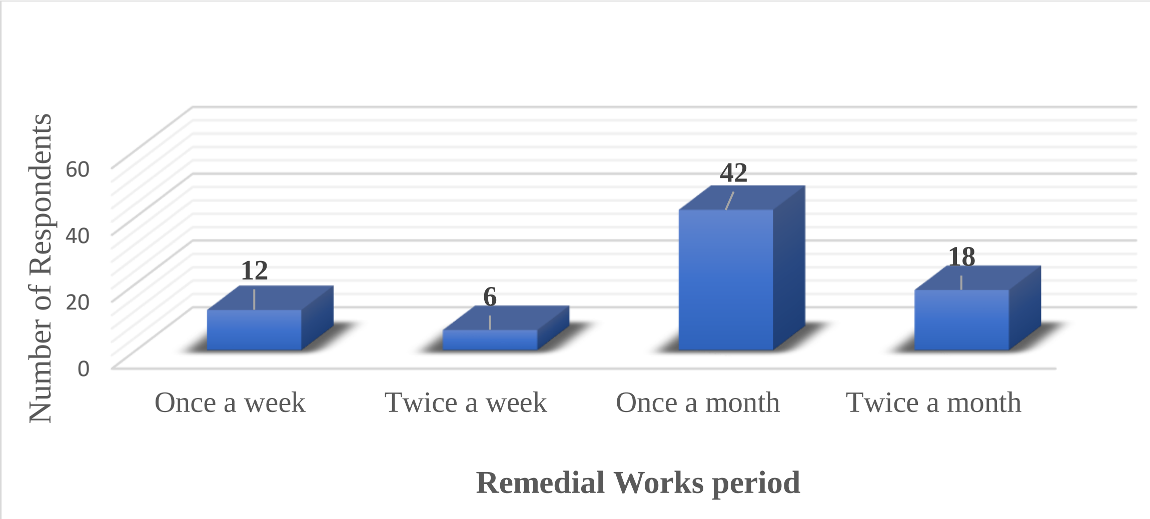

Figure 4.4 remedial works taken by respondents

The figure above indicates the remedial works, which can apply on site raised by the respondents and the result states 15% of the respondent's state that remedial works made in their site once per week, 7.7% twice per week, around 54% once per month and 23% twice per month.

4.6.2 Major Causes for those Remedial Works

The histogram below indicates the level of agreement of respondents regarding the major causes of the remedial works happened during the construction process: such that the effect of setting time was the major cause for the remedial works with RII value of 0.9. at the second rank respondent says climate effect was the major cause for such works(RII=0.88), another respondent illustrates that effect of curing have a RII value of 0.85, quality of ingredients,0.83 improper mix ratio 0.79 and test order by client 0.68.

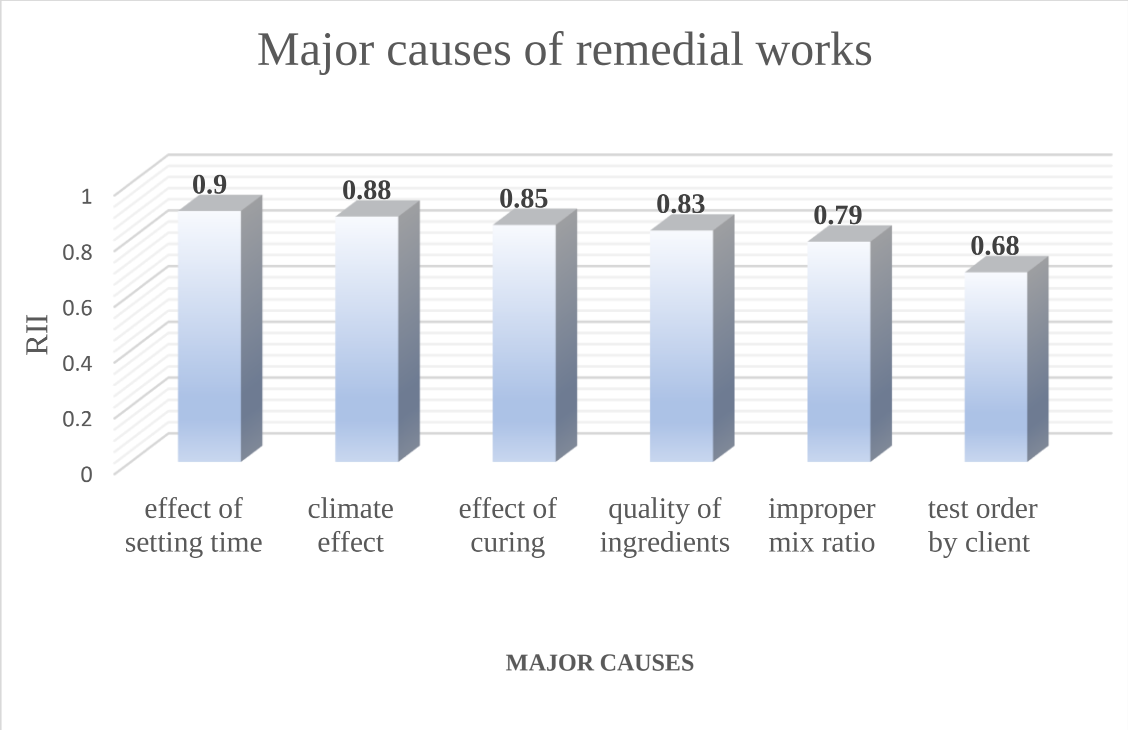

Figure 4.5: major causes of remedial works in building construction

As stated by the respondents, Better quality control can achieved in a factory assembly line setting than at the construction site. The construction activities in conventional construction was significantly affected by any climate change or weather condition interruptions. Meanwhile, in the prefabricated construction method, these kinds of interruptions were negligible, as the majority, i.e., about 80–90%, of construction activities happen in a factory. This also reduces the construction time and total cost of projects using the prefabricated construction method when compared to conventional construction methods.

4.6.3 Quality Measurement of Concrete Works

Quality of concrete ingredients and structures can measured before and after the production process: same to that the quality of precast concrete structures were measured before production through laboratory sample result and after production by different means such as hammer test, cube test and observations. Such that 75% of the respondent states both precast (after transportation) and cast in-situ structures can measure their quality through hammer test and the rest through cube test and observations. Before transportation, the quality of precast concrete materials can measure through laboratory results such as compressive strength and the quality of ingredient based on the specification.

Rebound hammer test is a nondestructive testing method of concrete, which provides a convenient and rapid indication of compressive strength of concrete. When the plunger of rebound hammer test pressed against the surface of the concrete, a spring controlled mass with a constant energy was made to hit the concrete surface to rebound back. The extent of rebound, which was a measure surface hardness, is measured on a graduated scale. This measured value is designated as rebound number or rebound index. A concrete with low strength and low stiffness absorbs more energy to yield in a lower rebound value. As per the Indian code Is:13311(2)-1992, the rebound hammer test have the following objectives

- To determine the compressive strength of the concrete by relating to rebound index and the compressive strength
- To assess the uniformity of the concrete
- Ta assess the quality of the concrete based on the standard specifications
- To relate one concrete element with other in terms of quality

Prior to conducting rebound test Inspectors should pay attention to the following considerations

- The testing surface must be at least 150 mm diameter
- If there is any free of moisture or water on the concrete surface must be removed prior to testing
- Do not test frozen concrete: should only be tested after it have thawed, since frozen concrete tends to have high rebound numbers
- Avoid direct testing over steel reinforcement when cover thickness is less than 20mm. its recommended to use rebar locator to avoid testing on shallow depth reinforcement

Discard reading differing from the average of ten readings by more than six units and determine the average of the remaining readings. If more than two readings rejected, discard the entire set of readings and determine rebound members at ten new locations within the test area.

4.6.4 Major Quality Related Benefits of Precast Concrete

These are the issues raised by respondents on the quality related benefits of prefabrication concrete comparing to concrete cast in-place.

Table 4.17: major quality related benefits of precast concrete

Advantage	RII	Rank
Erect at every season	0.97	1
Light weight	0.84	2
Easy for demolition	0.82	3
Better quality of materials	0.8	4
Easily reusable	0.78	5
Easy for sanitary and installation	0.74	6
Less leakage problem	0.49	7

As indicated by respondents in the table above, with the result of RII =0.97 state that precast structures can erect at every season without the effect of the climate but not in cast in-situ. Another quality related benefit raised by the respondents (RII=0.84) was precast structure are light in weight because they may design in hallow structure. In the third rank with RII=0.82 state that precast concrete method are easy for demolition and are reusable. They are also easy for sanitary and installation because these can considered during the design period and are easily reusable. If erected effectively precast are also free of leakage problem.

The data gotten from interview with the stakeholder of ECWC shown that the strength of precast concrete gradually increases over time and precast concrete product can provide a service life in excess of 100 years and they are non-combustible. Precast concrete structure resist more substances such as chemicals, weather etc.

Observed that the quality of work on some construction sites, especially the public sector are sometimes low due to the fact that batching, mixing, testing of concrete and other activities are not accurately controlled in the case of in-situ as compared to precast. Prefabricated components was produced under factory-controlled conditions where almost every activity is highly mechanized, to ensure that the components manufactured are of more quality in terms of the surface texture, strength and incorporating services accurately.

4.6.5 Major Reasons not to use Precast Concrete Method

These were major reasons not to use precast concrete materials stated by the respondents

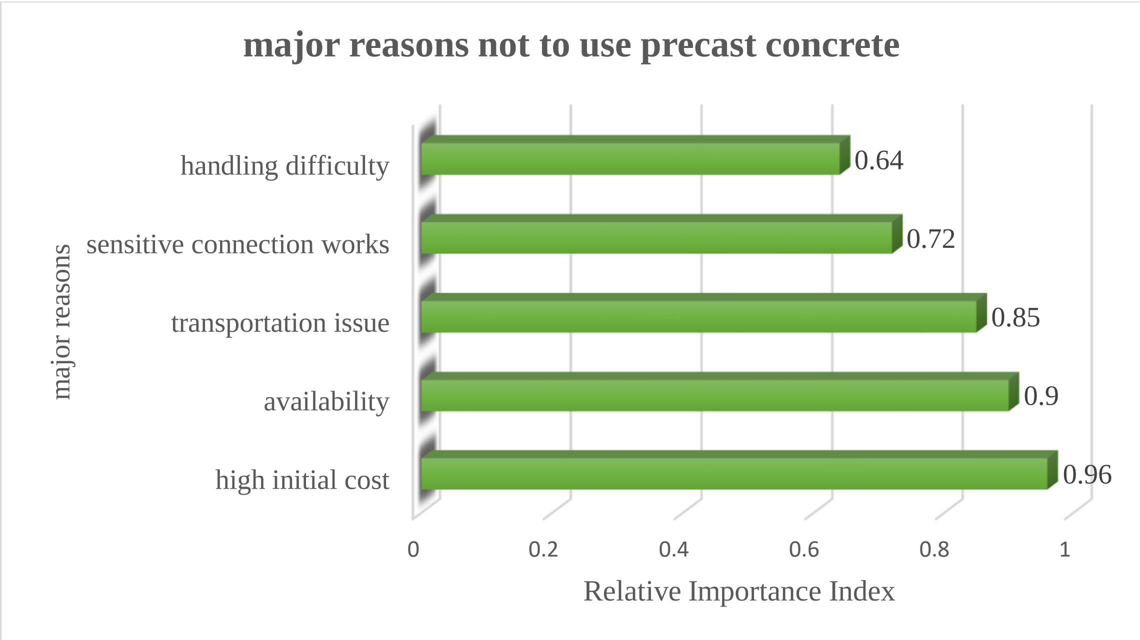

Figure 4.6: major reasons not to use precast concrete in building construction

The figure above depicts the main reasons of the stakeholders not to use prefabrication concrete in their building construction around my study area Mekelle city. The result indicates the first reason was in order to install the company a high initial cost was required with RII value of 0.96 and secondly raised reason was the availability of the material since precast concrete materials are only produced at the capital city of Ethiopia Addis Ababa and it was far apart from Mekelle. In addition to those there are another reasons of the respondents i.e. transportation issue from production site to construction site, their sensitive connection and a handling difficulty with RII= 0.85, 0.72 and 0.64 respectively.

As stated above one reason of stockholders not to use precast concrete materials were its high initial cost because for installing a Precast Concrete plant, heavy and sophisticated machines are necessary which requires high initial investment. A large scale of precast construction projects must be available to ensure sufficient profit.

Transportation issue: The construction site can be at a distant location from the precast Concrete plant. In that case, the precast members must be carried to the site using trailers. In many cases, the reduced costs of precast Concrete were compensated by the transportation cost.

Handling Difficulties: Proper care and precaution have to be taken during handling precast concrete. Usually precast members was heavy and large, which makes it difficult to handle without damage. Generally, portable or tower cranes was used to handle the precast members.

Sensitive Connection Works: Assembling of the precast members was one of the key points for ensuring strong structural behavior. Connections between several structural members (column, beam & slab) must be supervised and done properly to ensure the intended behavior of the connection such as simple, semi-rigid or rigid connections. Besides this, faulty connections may lead to water leakage and fail sound insulation and this may the main drawback of prefabrication.

4.7 Precast Concrete Construction Company

The development of the construction industry has been increased rapidly with the introduction of new system of construction and new technologies. Precast concrete technology was being used widely by many countries around the world, which was one of the most cost effective and quality monitored system. Due to the protective environment, the quality and efficiency can be monitored and safety can be assured. In order to improve and speed up the construction, division and specialization of the human workforce and interaction between the design and planning phase has to be carried out.

Figure 4.7: Precast concrete building elements

Many developing economies have been reported to be looking towards improving the quality of the products of construction and increasing the productivity of the sector with greater use of mechanization, prefabrication technology and upgrading the skill of workers. Precast concrete factory for building construction in Ethiopia is not broadly adopted due to many difficulties such that Ethiopian government cannot work on that sector and the stakeholders in building construction have not fully aware the benefits of the sector. Before 3 years Kality precast concrete factory were working on this but now it's not working on due to shortage of demand by the stakeholders. Ethiopian construction works corporation (ECWC) is working on this.

Table 4.18: precast concrete produced materials and demand level

Produced materials	Demand level		
	High	Medium	Low
Column		√	
Beam		√	
Slab		√	
Stair		√	
Wall			√

As stated in the table above the precast concrete building materials produced in ECWC was precast concrete column, beam, slab, stair and shear wall and their level of demand was medium for all except shear wall which have low level. This result indicates that the stakeholders in building construction (contractors, consultants and project owners) have not aware of the cost, time and quality related advantages of precast concrete.

4.7.1 Precast Concrete Component Test

The quality and consistency of products of precast concrete is something take very seriously. A sieve analysis, or gradation test, was a procedure used to assess the particle size distribution within aggregates. An aggregate with an acceptable particle size distribution depend on the particular product that the aggregate to be used for and the end use that the product required to perform product mold and, depending on the product being poured, cast in to a number of either 100mm or 150mm standard cube molds. The samples then left to cure under normal conditions. Once the samples have properly set, they removed from the molds and catalogued with identification and batch numbers. Cube samples then placed in to the concrete compression apparatus and crushed to destruction. The test results must indicate the maximum compressive strength of the concrete and results must recorded and filed. All the concrete used in Elite products is high strength $50N/mm^2$.

The sampling and testing of materials must begin early enough to insure acceptability of materials. Department inspectors will secure initial samples to verify the quality of materials as received from the sources. Plant control sampling or testing of materials from approved sources was not be required unless specifically noted. Materials must be sampled and tested in accordance with the following guide:

1. Portland Cement shall be obtained from an approved source. One Independent Assurance sample per month is to be obtained by the Office of Materials and Testing Plant Inspector and sent to the Forest Park Laboratory.

2. Fine and coarse aggregates shall be obtained from approved sources. The gradation shall be consistent. One Independent Assurance sample per month is to be obtained by the Office of Materials and Testing Plant Inspector and sent to the nearest Office of Materials and Testing Laboratory.

3. Admixtures shall be obtained from approved sources. One Independent Assurance sample per year is to be obtained by the Office of Materials and Testing Plant Inspector and sent to the Laboratory.

During Sampling and Testing of Fresh Concrete, Initial samples of concrete was obtained for determining compliance with air content, and slump specifications before any of the concrete was placed. A representative sample of concrete was obtained for each placement to conduct a slump test, air content determination, and to manufacture the predetermined number of cylinders. The concrete temperature were also obtained immediately after sampling. Results of all tests must recorded immediately after completion of the test. The sample of concrete for the test has selected at random between the first delivery of concrete and the last delivery of concrete.

When Curing Concrete, Special care shall be taken to prevent excessive evaporation or drying out of concrete. The surface of the concrete throughout the curing period must covered with a film of free moisture. Curing mats or curing enclosures shall completely enclose the members. No gaps or openings in the curing mats or enclosures that allow the concrete surface to become dry.

Immediately after the forms have been removed, the members shall be individually identified with an identification number and dated by the producer. This is necessary to insure that a record will be available of the exact location on the bed and date of placement of each member

During Handling Precast Members, Precast members cannot be lifted from the casting bed until the concrete has reached a compressive strength as specified on the Plans or at least 1500 psi (10 MPa). Units cannot transported or erected until they have reached the required design strength.

All these precautions and processes are gotten from the ECWC as a means of interview during my observation in their site and after the careful transportation, the precast member can be checked its quality by a means of hammer test and observation whether the material have the expected quality or not.

4.7.2 Challenges for adoption of Precast Concrete Building Construction

Precast building technology in Ethiopia was facing various challenges due to lack of awareness of advantages of precast, resistance to change, lack of expertise, lack of guidance, information and an assumption that precast was costly proportion in contrast to conventional without bearing in mind the overall benefits associated with it. In addition to those, there were a fact that the construction industry was not yet shifted to standardization. The major challenges of precast concrete in building construction raised by ECWC are:

- lack of policy related issues
- lack of awareness and high initial investment

A large amount of resource were invested initially to setup a precast concrete plant. Sophisticated machineries are expensive and require heavy investment. Precast concrete was mainly used in construction of high-rise buildings. Precast concrete were also utilized in construction of housing estates where the design of houses is uniform. Other projects where precast concrete is suitable are large stadiums, halls, factories, warehouses, airports and hangars. The scale of the construction projects using precast concrete must be large enough to ensure sufficient profit to offset the initial capital cost.

Figure 4.8: Fixed crane at precast production factory

Workers must be careful when handling precast concrete components to avoid damage. Precast components was manufactured in plants, which not always situated in the area of the construction sites. Precast components carried from the plants to the sites using trailers. Usually, precast components was large and heavy, creating difficulties in transportation. Upon arrival at the sites, Portable cranes or tower cranes could lift the precast components into place for erection. Usually, to increase the speed of construction, several cranes was used requiring large space. Proper construction planning and site management is necessary. Workers be well trained to ensure that precast components are positioned and connected properly to avoid cases where the columns, beams, walls, or slabs are not well aligned, dislocated or out of plane. Precast concrete system was not flexible when future modification must take into account. For example, the walls of a flat built using load bearing precast walls cannot be demolished for renovation purposes, as this will affect the stability of the entire precast structure.

The government of the country must work on the adoption of the precast concrete method implementing the factory in different regions of the county, supporting, and encouraging investors to work on this sector.

4.7.3 Current demand of Precast Concrete Components

The conventional method of concreting i.e. cast- in-situ was mostly used for various types of constructions. There were many drawbacks of this method like less quality, lesser speed of construction, high labour requirement and high demographic impact on the forests to timber formwork and scaffoldings etc. These drawbacks ultimately affect the structure. To overcome these drawbacks a new method of concreting can be adopted called as precast concrete method. Precast concrete method accepted worldwide for its advantages over conventional concrete method. As stated by ECWC, the current demand for the components of precast concrete for building construction in our country is low and the main reason for this is lack of awareness in the building construction stakeholders.

4.7.4 Promotion Mechanisms of Precast Concrete Building Construction

Prefabrication plays an important role in the construction of concrete structures worldwide, and was evolving continuously to cope with current society’s habits so that needs related to housing, commercial buildings and civil engineering works. In fact, industrialized construction may result in cost efficiency, good quality and environmentally friendly solutions, as well as the ability to adapt to market demands.

The precast concrete industry in Ethiopia is largely dominated by Government initiated projects for infrastructural development. However, it is effective if used for residential (low and high-rise) and commercial constructions because of their various favorable attributes. The efficiency, durability, ease, cost effectiveness, and sustainable properties of these products have brought a revolutionary shift in the time consumed in construction of any structure. Construction industry is a huge energy consuming industry, and precast concrete products was more energy efficient than its counterparts. The wide range of designs, colors, and structural options that these products provide is also making it a favorable choice for its consumers.

The main promotion mechanism of ECWC, which was the precast factory in Ethiopia, was through participation in bazar and exhibitions and through using the constructed buildings by this method as a reference.

4.7.5 Benefits of Prefabrication Concrete Method for Building Construction

Many advantages result from the industrial prefabrication of precast concrete elements. Apart from quality and precision, the Manpower requirements were reduced tremendously. The actual erection of the buildings on site was executed in a much shorter space and time compared to in-situ constructions. Prefabrication concrete is environmentally friendly and reduces noise and dust pollution in the construction site.

The table below indicates the level of agreements of respondent (the precast factory) on the advantage and disadvantage of precast concrete over cast in-situ in building construction.

Table 4.19: ECWC's level of agreement on the advantages of precast concrete

Criteria	Level of agreement				
	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Easy for installation and sanitary				√	
Reduce wastage					√
Easy for demolition				√	
Easy for design modification		√			
Less health and safety problem			√		
Leakage problem			√		
Limited site space				√	
High initial cost			√		
More adaptable for harsh condition					√
High aesthetic value				√	
Reduce construction cost				√	
Better quality				√	
Reduce time for construction					√
The profit depend on the repetition of components				√	
Reusable and long stay				√	
Light weight				√	
Needs large equipment				√	
Non environmental impact				√	
Higher total cost		√			

As indicated in the table above many advantages of precast concrete over cast in situ was stated. The company strongly agreed with precast concrete structures reduce wastage, more adaptable at harsh condition, and reduce time for construction. In addition to those ECWC agreed on easy for installation, demolition, have less health and safety problem, needs limited space for storage, have high aesthetic value, less total cost, better quality, long stay and reusable, light weight and have not impact for the environment. Prefabrication has been widely regarded as an endurable construction method in terms of its impact on the protection of the environment. An important aspect of this perspective was the influence of prefabrication on the reduction of construction waste and subsequent waste management activities, including classification, reuse, recycling and waste disposal.

Prefabrication is a productive construction technique in terms of time, quality, cost, productivity, safety and functionality. Since precast components was manufactured by industrial methods via mass production better to build a large number of buildings in a short time at low cost. The relevant advantages of this construction process gained from stakeholder interview are as follows:

- The division and specialization of the labour workforce.
- The use of tools, machinery, and other equipment, usually automated, in the production of standard, interchangeable parts and products.
- Precast concrete elements' erection is faster and less affected by adverse weather conditions.
- Factory casting allows increasing efficiency, high quality control and greater control on finishes.

5. CONCLUSION AND RECOMMENDATIONS

5.1Conclusion

The need for adoption of prefabricated concrete needs a guaranteed market to function and thus Contractors, Consultants and developers must be made aware of the potential of such a technology. Since most of the respondents (60%) have less awareness about this method, this paper try to create awareness about precast construction through discussing the advantages of precast concrete over cast in-situ.

The total duration and total cost estimation per cubic meter have been determined for both prefabricated and conventional construction and had known about the advantages and disadvantages of both prefabrication and conventional construction by the survey conducted in different companies. The comparison showed there was a huge time difference between the methods, the prefabricated construction was easy to work and reduces the project duration by 62.9% when compared to the conventional and it was the main advantages for prefabricated construction and it helps when there were labour shortage. At the same time, there was a slight cost difference, which the prefab was 12% less when compared to conventional on this study.

The effectiveness in prefabrication depends on the similarity of building elements such that Cost of pre-cast vary with the type and the size of construction. For a Small project, the cost of pre-cast increases due to no production of elements in bulk and unique nature. However, for bigger and similar projects the cost may decrease significantly due to the higher levels of production.

In the prefabricated concrete, the quality of the components was better controlled because the level and the accuracy of inspection was better than on-site built homes due to the environmentally controlled situation. This level of inspection was applied to every aspect of construction from wiring and plumbing to electrical fixtures. Therefore, there was minimal effect of climatic or weather conditions in case of prefabrication while in conventional construction, time spent due to bad weather or hazardous environments at the construction site increases the construction cost and project completion time.

Finally, the requirements of ideal project (delivering on the schedule, with in the budget and better quality) can achieve using prefabrication and the huge house demand can rectify within a short period.

5.2 Recommendations

The following recommendations were made after a critical look at the literature review and the findings of this study;

At present Ethiopia has just little skilled labour in construction industry regarding precast concrete and huge house shortage. To distribute prefabrication in Ethiopia, this percentage should be increased which can help in meeting the huge housing demand using prefabrication and the government through the Ministry of Housing development should come out with a deliberate policy to encourage and empower professionals in the built environment to adopt the usage of prefabrication as a criterion for project success. This should be a gradual process but not an event.

It is productive that investors of the country should work on the distribution of prefabricated concrete at different town of the country and can handle the high demand of home at short period, small budget and high quality.

Government should also take steps to support the construction industry by either providing them with direct financial grant or incentives to support professionals acquire equipment or buy, and make them available for stakeholders in the construction industry to easily assess them for use. the survey showed that, one of the major hindrances to the adoption and use of prefabrication is higher initial cost of equipment making it difficult for new investors in the sector to make it, and this helped promote and improve the use of prefabrication;

Finally, recommended that, since prefabrication method of construction is a new method of construction in the Ethiopian construction industry, future research into the concept of prefabrication should be conducted, in order to solve the misunderstanding of the concept to make stakeholders accept it.

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APPENDIX-ARESEARCH QUESTIONNAIRE

JIMMA INSTITUTE OF TECHNOLOGY

CONSTRACTION ENGINEERING AND MANAGEMENT STREAM

This study is being conducted to assess the knowledge, attitude and practice of people on the effectiveness of prefabrication concrete as a criteria for construction project success in Ethiopia particularly in Mekelle. The results of this survey would be used to draw strategies aimed at promoting the use of prefabricated building components to ensure project success of construction works in the construction industry with reference to cast in-situ. The General objective of this study is to assess the effectiveness of precast and cast in-situ concrete method in building construction projects around **mekelle** city. Your cooperation is needed in answering the questionnaire. Every piece of information you give would be treated confidentially and would be used only for academic purposes.

Concrete Prefabrication is the production of entire building, or significant concrete building constituents like column, beam, slab, shear wall, stair… offsite in a workshop background prior to fixing or assembly onsite.

If you have any enquiry please contact me through the following addresses.

GebremicaelTetemke

Post Graduate Student at Jimma University, School of Civil and Environmental Engineering, Construction engineering and management stream.

Email address: - gebremitetmeke@gmail.com

Phone number: - 09-13-78-53-08

Thank you in advance for your valuable cooperation!!

Please select with a tick **[√]** and comment where appropriate.

1. Profession________________________
2. Educational Status

☐ No ☐ College ☐ Degree ☐ Masters

3. Experience

☐ Below five years ☐ Five up to ten years ☐ Greater than ten years

4. Contribution

☐ Contractor ☐ Consultant ☐ Owner ☐ Others__________

5. What form of construction are you using on this housing development project?

☐ in-situ ☐ Precast ☐ Composite (combination of both)

6. Why did you choose this form of construction?

☐ Precast production company is not available locally, high transportation cost

☐ In-situ is easy for any irregular design but not precast

☐ Precast relatively offer short time and low cost and have better quality

☐ any other variables____

7. What is your perception for the construction form above instead of time & cost required to construct, and quality of materials in your project? 1=less 2=medium 3=more

Factor	Cast in-situ	Precast	Combined
Time			
Cost			
Quality			

8. What is your awareness about precast/prefabrication concrete in building construction?

☐ No aware ☐ Less aware ☐ Aware

9. What types of precast concrete materials are used in your project?

☐ Column ☐ Stair
☐ Beam ☐ Slab
☐ Wall ☐ Others____________

10. From your experience, is it possible to reduce the cost of building construction using precast rather than cast in-situ concrete materials?

☐ Yes ☐ No

11. If your answer for the above question is yes, please specify your level of agreement on what types of cost can be reduced?

Type of cost that can be reduced	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Labour cost					
Cost of formwork					
Scaffolding cost					
Risk cost					
Finishing cost					
Concrete cost					
Maintenance cost					
Reinforcement bar cost					

12. In your perception, is it possible to reduce the time required for construction using precast concrete instead of cast in-situ?

☐ Yes ☐ No

13. If your answer for the above question is yes, what types of time can be reduced, stipulate your level of agreement?

Factors	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Reduce time to erect and dismantle scaffolding and formworks					
Reduce time to cure concrete					
Reduce time to plastering and finishing's					
Time to mix concrete ingredients					

14. What is the status of your project?

☐ On time ☐ Delayed ☐ Ahead of schedule

15. If your answer for the above question is delayed, what could be the major reasons not being on time?

Cause for delay	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Form of construction used					
Design error					
Delivery of materials					
Remedial works					
Insufficient plant and equipment					

16. How often have been remedial works done?

☐ once a week ☐ once a month

☐ twice a week ☐ twice a month

17. Please State your level of agreement on the major causes of such remedial works?

major cause of remedial works	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
improper mix ratio					
effect of setting time					
effect of curing					
quality of ingredients					
test order by client					
climate effect					

18. How can it measure the quality of precast concrete materials after and before transporting to construction site? ____

____

19. What are the major reasons not to use precast concrete materials, state your level of agreement?

Major reasons	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
high initial cost					
Availability					
transportation issue					
sensitive connection works					
handling difficulty					

20. Please state your level of agreement on the major quality related benefits of precast concrete over cast in-situ ?

Major reasons	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Better quality of materials					
Not affect by climate condition of the site					
Erect at every season					
Easily recyclable					
Easy for installation and sanitary					
Light weight					
Easy for demolition					
Less leakage					

21. From your personal experience Please indicate your level of agreement for these listed factors where 1=strongly disagree 2= disagree 3= neutral 4= agree 5=strongly agree

Factors	Cast in-situ	Precast	Combined
Easy for installation and sanitary			
Reduce wastage of materials			
Easy for demolition			
Easy for Design modification			
Less Health and safety problem			
Leakage problem			
Limited site space			
Higher initial cost			
More adaptable to harsh condition			
High aesthetic value			
Reduced construction cost			
Reduced time for construction			
Better quality			

JIMMA INSTITUTE OF TECHNOLOGY

CONSTRACTION ENGINEERING AND MANAGEMENT STREAM

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Concrete Prefabrication is the production of entire building, or significant building constituent's like column, beam, slab, shear wall, stair… offsite in a workshop background prior to fixing or assembly onsite.

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Phone number: - 09-13-78-53-08

Thank you in advance for your valuable cooperation!!

Questionnaires for precast concrete manufacturing

. Please select with a tick **[√]** and comment where appropriate.

1. Factory name ______________________________
2. Experience in building industry_________________________
3. Please specify the produced precast components in your company and indicate the level of demand for the products **[√]**

Material type	Produced material	Demand level		
		high	medium	Low
Column				
Beam				
Slab				
Wall				
HCB				
Stair				

4. Please specify the current material cost and time needed to erect for these materials produced in your company?

Material type	Unit	Cost per unit	Production time/unit	Erection time/ unit	Transportation cost per km	Equipment cost per hr.
Column						
Beam						
Slab						
Stair						
Wall						

5. What type of tests can be made to check the quality of precast structures after and before mobilization to site?

____

____

6. What are the challenges for adoption of precast concrete construction in Ethiopia?

____

____

____

7. What is the current demand of precast concrete by the building construction sectors in your factory?

☐ High ☐ Medium ☐ Low

8. How could you promote your products to attract multi-users?

____

____

____

9. Please indicate your level of agreement for these advantages and dis advantages of precast concrete materials comparing to cast in-situ with the specified ratings where 1=strongly disagree 2=disagree 3=neutral 4=agree 5=strongly agree

No	Criteria	1	2	3	4	5
1	Easy for installation and sanitary					
2	Reduce wastage of materials					
3	Easy for demolition					
4	Easy for Design modification					
5	Less Health and safety problem					
6	Leakage problem					
7	Limited site space					

8	Higher initial cost					
9	More adaptable to harsh condition					
10	High aesthetic value					
11	Reduced construction cost					
12	Reduced time for construction					
13	Better quality					
14	The profit depend on repetition of the material					
15	Recyclable and long stay					
16	Light weight					
17	Needs large equipment's					
18	Non-environmental impact					
19	Higher total cost					

APPENDIX-B RECENT MATERIAL COST BREAKDOWN

concrete C-30

3.10 Daily out put ; 1.5 m3/day

A .MATERIAL					B.MANPOWER					C.EQUIPMENT				
TYP	UNIT	QTY.	RATE (BIRR)	COST PER UNIT	SKILL	NO	U,F	AILY RATE (BIRR0	ILY COST (BIRR)	TYPE	NO	U,F	ntal rate/hr (birr / hr)	Daily cost (birr)
grave	m3	0.75	361.15	270.86	masone	1.00	1.00	335.00	335.00	mixer	1.00	1	174.68	1,397.40
ceme	qtl	4	239.83	959.32	D. labour	6.00	1.00	110.00	660.00	vibrater	1.00	1	56.52	452.16
sand	m3	0.45	435.88	196.15	operator	2.00	1.00	175.00	350.00					
wate	m3	0.13	52.38	6.81	forman	1.00	0.25	350.00	87.50					
TOTAL ' A' (BIRR)				1,433.14	TOTAL 'B' (BIRR)				1,432.50	TOTAL 'C' (BIRR)				1,849.56
1.MATERIAL TOTAL " A "				1,433.14	2. MANPOWER TOTAL " B " DAILY OUTPUT				955.00	3. EQUIPMENT TOTAL " C" DAILY OUTPUT				108.80

"1" + " 2 " + " 3 " = BIRR **2496.94**

concrete C-25

3.9 Daily out put ; 1.5 m3/day

A .MATERIAL					B.MANPOWER					C.EQUIPMENT				
TYP	UNIT	QTY.	RATE (BIRR)	COST PER UNIT	SKILL	NO	U,F	AILY RATE (BIRR0	ILY COST (BIRR)	TYPE	NO	U,F	ntal rate/hr (birr / hr)	Daily cost (birr)
grave	m3	0.68	415.32	282.42	masone	1.00	1.00	335.00	335.00	mixer	1.00	1	200.88	1,607.01
ceme	qtl	3.60	205.81	740.90	D. labour	6.00	1.00	110.00	660.00	vibrater	1.00	1	65.00	519.98
sand	m3	0.46	435.88	200.50	operator	2.00	1.00	175.00	350.00					
wate	m3	0.12	52.38	6.29	forman	1.00	0.25	350.00	87.50					
TOTAL ' A' (BIRR)				1,230.11	TOTAL 'B' (BIRR)				1,432.50	TOTAL 'C' (BIRR)				2,126.99
1.MATERIAL TOTAL " A "				1,230.11	2. MANPOWER TOTAL " B " DAILY OUTPUT				955.00	3. EQUIPMENT TOTAL " C" DAILY OUTPUT				125.12

"1" + " 2 " + " 3 " = BIRR **2310.23**

Form work for footng ,column & beams

4.1 Daily out put ; 11 m2/day

A .MATERIAL					B.MANPOWER					C.EQUIPMENT				
TYP	UNIT	QTY.	RATE (BIRR)	COST PER UNIT	SKILL	NO	U,F	AILY RATE (BIRR0	ILY COST (BIRR)	TYPE	NO	U,F	ntal rate/hr (birr / hr)	Daily cost (birr)
timbe	m2	1.05	350.02	367.52	carpenter	1	1.00	325.00	325.00					
eucly	ml	4.6	15.65	72.01	ass. Carp	1	1.00	200.00	135.00					
eucl.	ml	1.68	13.92	23.38	D.labour	1	1.00	180.00	110.00					
nail	kg	0.2	85.51	17.10	forman	1	0.25	350.00	87.50					
TOTAL ' A' (BIRR)				480.01	TOTAL 'B' (BIRR)				657.50	TOTAL 'C' (BIRR)				
USAGE				5										
1.MATERIAL TOTAL " A "				96.00	2. MANPOWER TOTAL " B " DAILY OUTPUT				59.77	3. EQUIPMENT TOTAL " C" DAILY OUTPUT				

"1" + " 2 " + " 3 " = BIRR 155.77

Form work for suspeneded

4.2 Daily out put ; 10 m2/day

A .MATERIAL					B.MANPOWER					C.EQUIPMENT				
TYP	UNIT	QTY.	RATE (BIRR)	COST PER UNIT	SKILL	NO	U,F	AILY RATE (BIRR0	ILY COST (BIRR)	TYPE	NO	U,F	ntal rate/hr (birr / hr)	Daily cost (birr)
timbe	m2	1.05	350.02	367.52	carpenter	1	1.00	325.00	325.00					
eucl	ml	6.75	17.39	117.41	ass. Carp	1	1.00	135.00	135.00					
eucl.	ml	6	13.92	83.49	D.labour	1	1.00	110.00	110.00					
nail	kg	0.25	85.51	21.38	forman	1	0.25	350.00	87.50					
				589.80	TOTAL 'B' (BIRR)				657.50	TOTAL 'C' (BIRR)				
1.MATERIAL TOTAL " A "USAGE				4.00 147.45	2. MANPOWER TOTAL " B " DAILY OUTPUT				65.75	3. EQUIPMENT TOTAL " C" DAILY OUTPUT				

"1" + " 2 " + " 3 " = BIRR 213.20

Steel Reinforcement Bar Diamatere 12 MM

5.3 Daily out put ; 80 kg/day

A .MATERIAL					B.MANPOWER					C.EQUIPMENT				
TYPE	UNIT	QTY.	RATE (BIRR)	COST PER UNIT	SKILL	NO	U,F	AILY RATE (BIRR0	ILY COST (BIRR)	TYPE	NO	U,F	ntal rate/hr (birr / hr)	Daily cost (birr)
deformed bar daiametr 12 MM	kg	1.05	46.81	49.16	Bar Bende	1	1	337.50	337.50					
wire	kg	0.06	46.01	2.76	D. Labour	1	1	110.00	110.00					
					Forman	1	0.25	350.00	87.50					
TOTAL ' A' (BIRR)				51.92	TOTAL 'B' (BIRR)				535.00	TOTAL 'C' (BIRR)				
1.MATERIAL TOTAL " A "				51.92	2. MANPOWER TOTAL " B " DAILY OUTPUT				6.69	3. EQUIPMENT TOTAL " C" DAILY OUTPUT				

"1" + " 2 " + " 3 " = BIRR 58.60

APPENDIX-C RESEARCH INTERVIEW QUESTIONS

1. What is the design service life of precast concrete materials?
2. What are the main problems not to use precast concrete in building construction?
3. What are the relevant advantages and disadvantages of prefabricated construction process?
4. Why combined form?
5. What is the role of Precast to achieve green building goals?
6. What is your perception in precast concrete and their time, cost and quality related advantages?
7. How can one decide on which form of concrete construction method is effective precast or cast in-situ?
8. What is your perception about “ideal project”?