ADDIS COLLEGE

MODERN METHOD OF CONSTRUCTION IN ETHIOPIAN CONSTRUCTION PROJECT. THE CASE OF SELECTED PUBLIC BUILDING PROJECTS IN ADDIS ABABA

MSc. Thesis

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DEPARTMENT OF CONSTRUCTION TECHNOLOGY AND MANAGEMENT

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I, the under signed, declare that this thesis entitled “Modern Method of Construction in Ethiopian construction project. The Case of Selected Public Building projects in Addis Ababa”, is my original work and has not been presented for a degree by any other person to the best of my knowledge, and that all sources of material used for the thesis have been duly acknowledged.

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CERTIFICATE

This is to certify that the thesis prepared by Mr. Leta Fufa " Modern Method of Construction in Ethiopian construction project. The Case of Selected Public Building projects in Addis Ababa ". And it is submitted as partial fulfilment for the requirement degree of masters of science in Construction Technology and Management complies with the regulations of the university and meets the accepted standard concerning the originality, content, and quality.

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ABSTRACT

The modern methods of construction primarily involve the manufacture of components in factories, with potential benefits such as faster construction, fewer housing defects, and reductions in energy use and waste. Developing countries are dependent on the growth and development of physical infrastructures and construction industry plays a vital role for countries like Ethiopia. Conventional method of construction nowadays, are causing over costing, time consuming, producing compromised products and not in line with the current technology. Therefore, the aim of this study is to assess the Modern Method of Construction (MMC) in selected building projects in Addis Ababa. For achieving this study, descriptive and qualitative designs have been used. Structured questionnaires have been used for the collection of data. 51 questionnaires have been distributed to respondents. 84% of the distributed questionnaires were valid and used for the analysis of the study. 5 questionnaires were not collected from the respondents and out of the collected questionnaires were obtained in valid (>50% of the questions were not answered). The data of the study have been presented using tables, frequencies and figured supported with excel of version 2016 and Statistical Package for Social Science (SPSS). Finally, the employees of the construction projects have not enough concept, insufficient knowledge and inadequate knowhow of the process of Modern method of construction (MMC). MMC is found to be efficient on the construction industry in terms of cost, time, quality and flexibility as compared to conventional construction method. It is found that, MMC has a great impact on the area of construction industry.

Key words*: **Modern Method of Construction, offsite construction, construction project, pre fabrication,***

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CHAPTER ONE

1. INTRODUCTION

1.1. Background of the study

The past few decades have seen an increasing policy and business interest in modern methods of construction (MMC) across countries, coupled with a growth in the emerging technologies facilitating contemporary MMC practices. However, modern methods of construction are not a new phenomenon. There have been many attempts across different housing markets and through different tenures to implement large scale industrialised building systems, conventionally known as prefabricated houses. In the past, serious quality issues ultimately led to the abandonment of this form of development and the stigma associated with failed past practices has made prefabricated housing unattractive to construction industries around the world as well as to end users (Sarah Payne, 2023).

Nonetheless, contemporary modern methods of construction that typify industry practice in the early 21st century do bring about numerous benefits for the development industry, one of which is better building quality. Evidence from (Ali & Al-Zaid, 2022), suggests the following development benefits: 1) better building quality and high-quality control, 2) improvement of the speed of construction and improved quality control, 3) reduction of the overall cost of construction, 4) reduction of the construction waste, 5) reduction of the environmental impacts, 6) improvement of working condition and health and safety of the workers, 7) decreased labor, 8) lower maintenance and repairs, 9) reduction of the environmental impacts to residents around construction sites; and 10) decrease in disputes during construction.

In addition to these multiple development benefits, MMC has also been hailed as a policy solution for addressing systemic housing supply problems, which are a feature of many market-led housings systems around the globe. Systemic supply problems, while institutionally complex, are caused to varying degrees by inter alia restrictions in land supply, planning constraints, access to finance, skills and materials shortages and more controversially the speed of development. In this regard, modern methods of construction represent a faster and more efficient form of housing construction, which can increase build out rates and have the potential to address deficiencies in the design value of new housing as well as contributing to increased social housing (Thomas et al., 2022).

The concept of construction technology aims to clarify the use of technology and construction for buildings, where technology is defined as a way of thinking and solving problems. This way of thinking about the use of knowledge, information, and skills leads individuals to the desired results. It thus aims to satisfy humans' needs and increase their capabilities. Indeed, the optimal use of scientific knowledge as well as its application and adaptation can serve humans and improve their well-being (Politecnico & Milano, 2018). Construction is defined as "the part related to the design of the structural fabric and how its components are put together" and is based on three issues: materials, construction methods, and systems. Construction is linked to several factors such as (i) the number of pieces to be connected; (ii) the connection joints; (iii) the place of the assembly of the standardized, ready-made structural elements in the case of on-site installation and assembly of materials in the case of the on-site construction of buildings; and (vi) the construction time and materials where the construction items consist of building materials and technical systems. The construction process is based on the materials and methods used according to the nature of the construction system followed (Ali & Al-Zaid, 2022).

In the current situation, as the world's population grows at a faster rate, the demand for housing is increasing, forcing the aggregation of houses to become the most pressing need of global growth. This necessitates the shortest possible production period in order to meet demand, which is only possible if current development processes are implemented (B. A. Sheikh, 2021). There are many inventions that are used today in the modern technology of construction, including different construction materials in the construction industry, additional metals, different types of machinery, etc. In this competitive world, it has become increasingly necessary to deal with neighbouring countries in terms of infrastructure growth. All of these modern techniques help to reduce additional costs, reduce labour costs, reduce transportation costs, longevity of building materials, and much more. With newly coming technology construction operations, materials and their maintenance based on the requirements of low power consumption, low CO2 emissions, serviceability and long- lasting quality, the construction industry is adopting various new methods to upcoming creative construction techniques and methodology (Gawad, 2022).

1.2. Statement of the problem

Construction projects are notorious for cost overruns and delays in project completion. Over the past three decades, globalization and competition have become increasingly fierce (Abebe,

2020). therefore, globalization and competition are the most important reasons every construction company needs to improve and calibrate its system to achieve its goals with management tools. Several reports have criticized the construction industry, especially in terms of productivity, quality and quality systems, and most project managers focus on cost and time rather than the quality of the project. construction, but researchers point out that more attention should be paid to quality (Momoh, 2022). Construction projects are notorious for cost overruns and delays in project completion. Over the past three decades, globalization and competition have become increasingly fierce. therefore, globalization and competition are the most important reasons every construction company needs to improve and calibrate its system to achieve its goals with management tools. Several reports have criticized the construction industry, especially in terms of productivity, quality and quality systems, and most project managers focus on cost and time rather than the quality of the project. construction, but the researchers emphasize that more attention should be paid to quality (Gawad, 2022).

As (B. Sheikh, 2021) noted ,many project in developing countries face considerable time and cost over runs ,fail to fill their proposed aim or even totally terminated and abandoned before or after their completion. Moreover, the progress of the construction industry in developing countries generally lags far behind from other industries in those countries in those countries and their counterparts in developed nations. The construction industry in developing countries failed to meet expectations of governments, clients and society as a whole as (Ali & Al-Zaid, 2022) generally concluded. Successful project can be defined as achieving the project objective as on time, within cost, and quality (scope) to meet client's prerequisite.

The MMC is growing in Ethiopia at a high-speed and it brings a great development to the country and to the city specifically, but it is also undeniable that there are various quality problems arising with it as well. The MMC construction in Ethiopia is challenged by several problems which tend to confront the sector and thus making efforts at developing the MMC construction very difficult and complex. Different MMC practices and product have been developed that have completely changed the behaviour of housing from that it had been before. This changes is amazing and is in the way to bring more and more development in construction sector (Politecnico & Milano, 2018). Nowadays, MMC plays an important role in the quality of the deliverable of construction projects.

Conventional method of construction nowadays, are causing over costing, time consuming, producing compromised products and not in line with the current technology. Therefore, the aim of this study is to assess the MMC in selected building projects in Addis Ababa.

1.3. The research motivations

The researcher chosen the title because most construction project in this country have quality defects and problem in on time delivering the projects to the client. This research tries to contribute knowledge on how MMC contribute to quality and save time in construction projects.

1.4. Research questions

1. What are the efficient MMC types and method of its practice in construction projects in Addis Ababa.?

2. What are the impacts of Modern Method of Construction on construction projects in Addis Ababa?

3. What strategy is applicable for the application of MMC method in construction projects in Addis Ababa?

1.5. Objectives of the study

1.5.1. General objective

The general objective of this research is to assess Modern Method of Construction in Ethiopian construction project. The Case of Selected Public Building Addis Ababa.

1.5.2. Specific objectives

In order to achieve the main objective, the specific objectives were:

- To assess current practices of modern method of construction in selected building construction projects in Addis Ababa.
- To analysis the modern method of construction in selected building construction projects in Addis Ababa.
- To investigate the impact of modern method of construction in selected building construction projects in Addis Ababa.

1.6. Scope of the study

This research paper focuses on the application of MMC technology by selecting representative residential building construction projects in Addis Ababa that have already applied MMC in their project. The study is limited to residential buildings that have applied MMC and geographically to Addis Ababa city.

1.7. Significance of the study

The findings if this study will benefit the stakeholders in the construction industry, policy makers and myself; considering that MMC plays an important role in the quality of construction works, cost-minimizing, and time saving aspect of construction project management.

For the client

Quality assured product: as reported in the literature reviews, off-site construction method (MMC) products are better than conventional products. This assures that MMC provides a quality assured construction products to the end users, clients and/or customers. On time delivery of construction project: in-site work needs many things like regulatory permission, space for work and working space, suitable condition. However, the actual condition of site has many obstacles. The regulatory body may restrain you to stop work, rain may force you to stop work. There are many reasons that forced you to stop and delay your work above your control. This in sum leads an extension of schedule of a project. But, if off-site construction is preferred to on-site construction, these reasons of delay may be minimized. Cost effective construction project: off-site products minimize overhead costs. In on-site production there are many factors to delay a construction scheduling like natural disaster (rain). However, in the off-site production, the necessary materials are produced at the desired time and can be constructed at any time. This in return saves overhead costs and other costs related with time.

For the contractor

Reasonable profit: contractors' works for profit. This profit may be gained in different methods. In MMC, because projects are completed at the budgeted cost at the required time and required quality, the contractor receives his/her profits without any claim, dispute or other because the client is happy of the MMC products. Agreement with his client: because the construction

product is completed on budget with the required quality in time, the client and the contractor loved each other with the exposure of work. Good construction progress: if contractors finishes their work to the required level in terms of cost, quality and time, they build a construction friendly progress with their clients. The satisfied clients give the contractor other projects as a reward in response of good work performance.

For environment

Reduces noise: for the production of projects, many equipment is deployed. Like, mixer, vibrator, cranes, concrete trucks and concrete pumps. The combination of the sound of these equipment disturbs the environment. However, off-site production does not have this trend. Because the construction components are already produced in area far from the environment. Eliminates Congestion: for the production of projects, many equipment is deployed. Like, mixer, vibrator, cranes, concrete trucks, concrete pumps and many workers. This leads to traffic congestion in the area of construction. However, MMC does not practice this. Because the components of the project are produced in an off-site and only limited equipment and skilled workers are needed. Therefore, no congestion on site.

1.8. Organization of the paper

The general outline of this thesis report is as follows: -

Chapter one: -Introduction This chapter has introduced the core issues to be addressed in the thesis. It gives a broad background and history of Modern Method of Construction, presents the problem statement and propositions, research question, articulates the objectives and justifications for the study, and puts forward the scope and the limitations of the study.

The next section is Chapter two. In Chapter two: - Literature review (detailed and contextual): This chapter, while intricately related to chapter two, presented the context of the study. It develops the conceptualizations in chapter two into analysis and understandings of the Concepts, principles as well as best practices associated with the major issues of Modern Method of Construction. It presents the literature foundation for the research instrument as well as the preferred practices and previously worked researches as a reference base for the analysis and discussion chapter.

Chapter three: - Methodology The chapter systematically formulates the research methodologies and techniques employed for the study. It provides a description of the

methodologies and approaches employed. Within this framework, the chapter stereotypes the cases selected, the data sources used and the data analysis techniques employed.

Chapter four: -Analysis and Discussion: The chapter analyses and interprets the data collected and compares the findings with previously worked researches and theoretical justifications. It presents descriptions of the compliant handling construction risk management and their management as practiced by the targeted subject. The chapter also presents analysis and critique of the practices as compared with theories and international practices and suggestions of better practice based on the gathered data.

Chapter five: - Conclusion and recommendations the chapter, in light of presenting major findings of the study the conclusion. It also presents recommendations for future study.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Theoretical review

In this section definition of basic terms, concepts and ideas of Modern Method of Construction are discussed.

2.1.1. Concepts of Modern Method of Construction (MMC)

MMC is a generic term used by Government for alternative methods of off-site manufacturing (OSM). Term of "modern methods of construction" (MMC) comes from the United Kingdom as a common name for off-site and on-site methods of construction. Modular constructions consist of three-dimensional objects known as modules (off-site methods of construction). Modules are joined together at the construction site. Currently, the construction of modular schools in Slovakia is supported by the state government. This paper presents the advantages and disadvantages of MMC emerging at the technological preparation and implementation (Hashemi, 2017).

The modern methods of construction primarily involve the manufacture of components in factories, with potential benefits such as faster construction, fewer housing defects, and reductions in energy use and waste. All of which offer significant potential to minimize both construction waste and construction safety risks. On-site MMC refers to modern methods of construction which brings together systems or components that are predominantly assembled on site. Virtually all high quality products are built in factories around the world. Cars, planes, ships, computers, printers, cell phones – even the pen you write with – are built in factories. In addition, even homes built on site use many components that were produced in factories (Lychgate Projects Ltd, 2016).

2.2. Requirements for Construction Industry Construction

Construction industry has long been under the influence of costs competition. Regarding competitive conditions and variables such as population changes, weather conditions, and international competition, construction industry in long term needs numerous renovations and permanent match with customer requirements (Švajlenka & Kozlovská, 2018). One of the main challenges in construction industry includes renovation of residential and trade buildings in

terms of energy efficiency, time and cost. For example, approximately 88% of present buildings consume two times more energy compared with new buildings; thus, there is a high need for using Modern materials and technologies in energy management and insulation system as well as optimal, renewable energy resources (Sardén & Engström, 2010). Construction industry will face other challenges in future including combination of functions and maintenance of values of different parts of building such as meeting growing needs in design, development of safety-oriented structures by considering increase in environmental and touristic risks, economic use of energy and materials through production of special construction materials, globalization of regulations while they are in different regions. Renovation in construction by considering circumstances and regulations as well as common social trend and changes related to demand and supply sector need coordination of all relevant beneficiaries (Politecnico & Milano, 2018).

2.2.1. Modern Construction

The dominant path of politics for assurance of productivity of new buildings include development, promotion, and implementation of construction plans and goals which are widely different, depending on weather, economic welfare, market maturity for efficient and Modern constructional materials (S. Green, 2021). Considering rapid economic growth and increase in population in many developing countries, significant works will be performed on buildings by using Modern materials and efficient energy, with developed construction in next decades. Many buildings of these countries have been built by old design, and inefficient products, and optimum views of designers and installers have not been applied in their construction, and these countries do not access to training for development of labor force (Politecnico & Milano, 2018).

According to the study made by (Kier Group, 2020), plant manufacturing process include approval of design by the end user and regulatory authorities, assembly of module parts in a controlled environment, transportation from modules to final destination, and installation of modular units. New constructions shorten the period of construction, reduce the usage of financial resources and supervision costs, and they are cost effective and are not time consuming. As confirmed by (Švajlenka & Kozlovská, 2022), modern construction techniques based on modular method are useful in some significant areas including low production of wastes, low confrontation of materials with bad weather, low interferences in site, safer construction, flexibility, and compatibility.

2.2.2. Smart Building

Based on the work performed by (Waste & Resources Action Programme, 2007), smart building is one which its control subsystems are designed and implemented within logical predefined framework suitable for building use. Law of smart building says: real costs of building not only includes construction costs but also includes strategic costs and maintenance costs. Smart building reduces such costs by integrated automatic control, communication and management system (Politecnico & Milano, 2018). By considering the costs of a building occurred during its life, it is evident that maintenance has the highest share in current costs of a building. In this respect, maintenance costs are reduced nearly 58% and then, the return of costs provides many welfare facilities.

One of the important advantages of smart system is using them for convenience. Goals of main policy of construction include energy efficiency, reduction of environmental effects of construction materials and technologies, or use of global design which results in a practical method for development of standards and instructions for safety, convenience, and environmental effects. Fundamental setting is important for creation or enhancing buildings, development of standards and instructions including construction industry experts such as engineers, developers, and expert drawers (RICS, 2018).

2.2.3. Integrated Construction and Enhancement of Integration of Construction Because

As of (Tara Flynn, 2022), because of growing population, increase in demand for construction in high volume and within minimum period of time, at lowest price and with the highest quality, construction industry is directed towards construction of light, movable industrial buildings which are easily installed. In line with this (Politecnico & Milano, 2018), construction system is development of a system for construction of buildings or a set of building elements which are assembled through various methods so that various building arrangements are created, and it includes all practices required for special type of building construction together with all techniques and executable methods . Such system includes various technical and management methods for production and assembly of elements for specified goal and it is a set of related elements interacting so that they can provide specified function of building (Jones, 2009).

Construction system usually is based on non-traditional and industrial methods. In this respect, it poses increasing needs of people to residential and non-residential building, necessity of application of Modern methods and procedures for increasing the speed of construction,

making light, increase in useful life, as well as strengthening the buildings against earthquake (Nathan, 2015). Integrated construction for construction residential buildings is effective for weak economic sector. This method is mostly guaranteed in three-floor projects and for encouraging people to use prefabricated houses because of safety, fast construction, longer life cycle, and higher quality. More resistant, durable buildings can be constructed through using technical facilities and specified economic and financial resources and by exploitation of Modern technologies in construction engineering; furthermore, it leads to increase in the speed, ease, and simplicity of various parts of the task. Change in construction techniques and exploitation of Modern technologies and materials are essential and necessary for increasing the speed of construction and increasing the useful life and reduction of construction costs (Kier Group, 2020).

2.2.4. Next generation materials and use of Modern construction technologies Modern

Modern construction materials and technologies can play significant roles in productivity and energy saving and reduction of costs (Politecnico & Milano, 2018). An overview on construction technology during the last 50 years, it is found that Modern materials have played a significant role in energy saving, cost saving, and even the duration of construction. Generally, development of Modern technologies and products and access to saturated market need appropriate politics in the path of market growth and maturity (Avenue & Keynes, 2018). Initially, core essential policies for encouragement of development of Modern technologies are seen through case studies and market incentives and system advantages. Many suppliers of construction materials serve the global market so that products should be developed at global scale. Wider global markets can provide more potential producers and investors.

According to the investigation made by (S. D. Green, 2022a), application of Modern construction technologies always have led to some problems for manufacturing. Technology not only includes Modern techniques but also includes application of special technology by considering the economy dominating on culture of customer community, ease and continuity of production, capabilities and technical characteristics and their applications. The items which should be considered before using a technology in construction design include work volume, problems related to manpower, access to construction materials, height of floors, method and level and term of investment, architecture dominating the set, capability for prefabrication buildings, period of project, and selection of appropriate technology. For better use of Modern

construction technologies and achieving better choice and ease of decision making, construction methods are divided into 7 categories according to (Politecnico & Milano, 2018): construction by elementary methods, construction by traditional and prevalent methods, construction by advanced methods, industrial construction, light pre-fabrication, semi-heavy prefabrication, and heavy prefabrication.

2.2.5. Reduction of construction costs

Costs may change due to pressure in scheduling delivery and higher volume of construction which lead to innovation in construction, materials, equipment, quick and high-quality construction methods, and increased use of technology, disregarding the size of construction (Rod MacEachrane, 2016). More works need to be done for reduction of costs and increase in function accessed by developers and designers for gaining effective construction and development of standard technique. In advanced mature markets, the focus is on alternative cost-effective buildings within a long term investment, needing more initial finance (Tara Flynn, 2022). Reduction of initial costs and an increase in annual savings for improvement of returns in investments have resulted in more markets absorbing advanced construction plans. It is not possible to develop special criteria suitable for costs and functions across the world because of weather, tenant behavior, construction practice, and availability of resources (RICS, 2018).

Present focus is on moving present buildings toward Modern construction and higher level of function. Transference of movement to this side needs fast establishment of wide range of advanced construction technologies, which costs a lot and needs higher investment costs. There are different methods for answering challenges of time and cost, inadequate work force and insufficient high-quality buildings in various technologies of construction, integrated and prefabrication (Sanna, 2018). Following items play significant roles in reduction of construction costs: optimum application of all production and service capacities, and true management, training and development of culture of growth and productivity and targeting work force, management of capital investment costs, energy costs management and loss of resources, management of reduction of wastes of resources, enhancement of quality, improvement of process and level of service for increasing the speed, identification and removal of non-value-added practices, parallel practices, reduction of manpower share in staff section into executive, innovation in supply of service and increase in competitiveness (Politecnico & Milano, 2018).

2.2.6. Modern construction systems and materials

Today, methods for construction of residential buildings in communities with high growth of population and insufficient number of accommodation have been designed and developed based on minimum need for machineries, equipment, and skilled manpower (Politecnico & Milano, 2018). In this respect, application of lightweight materials and parts and elements which can be moved and installed easily and quickly is necessary for solving housing problem (Lychgate Projects Ltd, 2016). For solving housing problem in state, similar methods and experiences of other countries are studied, and after matching methods with climate, and geographical and cultural properties of Iran, some appropriate methods are used based by observing technical, executive, economic conditions of state. Next section presents some systems which can be used as proper construction methods after being modified (Yasin, 2019).

2.3. Historical reasons for using off-site manufacturing

After the First and Second World Wars due to post-war shortages of materials, along with a lack of skilled labour, it became necessary to consider alternative methods of construction to resolve the undersupply of housing. Successive Governments gave generous funding to non-traditional system building methods.

Renewed impetus to use system housing arose due to a combination of social and political pressures, to re-house people displaced by the major slum clearances of the late 1950s and 1960s. The 1970s saw a public reaction against pre-fabricated system buildings, largely as a result of high profile failures such as Ronan Point, East London. In 1982, 27% of all new houses in the UK were constructed from timber frame (Thomas AFarrell PAuchterlounie T, 2006). However, a popular investigative television programme, 'World in Action' (1983) destroyed confidence in timber frame construction for housing. It highlighted the vulnerability of poorly constructed timber-frame housing. This caused the market to plummet to 5% of the share in the domestic housing sector overnight (Payne & Serin, 2023).

2.4. Empirical Reviews MMC

The reputation of the United Kingdoms' construction industry has been in decline for a number of years. With the under investment, lack of training, the demographic shift and a lack of innovation in the construction industry; the Deputy Prime Minister, John Prescott commissioned the 'Construction Task Force' chaired by Sir John Egan to report on the scope

for improving the quality and efficiency of the UK construction industry (Thomas AFarrell PAuchterlounie T, 2006). The Construction Task Force compared the construction industry with other industries, on quality and efficiency; the outcome was unfavourable. It compared construction with the manufacturing industry as to how that industry had met challenges, and improved in recent years, on the delivery of goods to its customers in both time and quality, increasing its profits in so doing. However, the construction task force team repeatedly heard the claim that construction is different from manufacturing because every product is unique (Yasin, 2019).

In response to affordability of construction in terms of housing and transportation the average size of households is in decline caused by divorces and single families (Švajlenka & Kozlovská, 2018). In addition, there is a demand for more housing due to a range of demographic factors along with increasing life expectancy and movement of people to areas with economic growth. With this in mind, The Chancellor and The Deputy Prime Minister set up a review of housing supply in the UK on the 9th April 2003. This culminated in a report, known as 'The Barker Report' published along with the Budget in March 2004 (Thomas AFarrell PAuchterlounie T, 2006).

The concept of construction technology aims to clarify the use of technology and construction for buildings, where technology is defined as a way of thinking and solving problems. This way of thinking about the use of knowledge, information, and skills leads individuals to the desired results. It thus aims to satisfy humans' needs and increase their capabilities. Indeed, the optimal use of scientific knowledge as well as its application and adaptation can serve humans and improve their well-being. Construction is defined as "the part related to the design of the structural fabric and how its components are put together" and is based on three issues: materials, construction methods, and systems (S. Green, 2021). Construction is linked to several factors such as (i) the number of pieces to be connected; (ii) the connection joints; (iii) the place of the assembly of the standardized, ready-made structural elements in the case of on-site installation and assembly of materials in the case of the on-site construction of buildings; and (vi) the construction time and materials where the construction items consist of building materials and technical systems. The construction process is based on the materials and methods used according to the nature of the construction system followed (Ali & Al-Zaid, 2022).

2.4.1. Project performance

In the construction industry; time, cost and quality have been defined as the important criteria of measuring success. However, other several ideas have appeared from different researchers. the study of project success and the critical success factor (CSFs) are considered to be a way to improve the effectiveness of a project (Švajlenka & Kozlovská, 2018). There is still a disagreement between project management research as to what composes project success and how it is to be measured (Committee, 2019).

(Jones, 2009), pointed out that it is still not clear how to clear how to determine project success since project stakeholders perceive success or failure factors differently. They assumed that project success should be viewed from different perspectives of the individual owner, developer contractor, use, and the general public.

(Mekonnen, 2017), clarified that the most suitable criteria for success are the project objective. The point to which these objectives have been met determines the project or failure of a project. The criteria for success of the project management effort tend to be restricted top cost, time and quality performance. Although, when measuring project success, one must consider the objectives of all stake holders throughout the project life cycle and at all levels in the management hierarchy. Therefore, to believe the, with such a multitude of objective, one can objectively measure the success in measured both objectively (cost and time) and subjectively (Rushton, 2022). (Kyjaková & Bašková, n.d.) explain definitions of project success, and presents a list of critical success factors that can affect project performance at different stage of a project life cycle. As he mentioned, the definition of project success has changed over the years.in the 1960s, project success was measured entirely in technical terms: either the product worked or it did not. In the 1980s, the following definition for project success was offered (*MODERN METHODS*, 2021): project success is stated in term of meeting three objective: completed on time, completed within budget, and completed at the desired level of quality.

The quality of a project was defined as meeting technical condition. Note that all three of these measures are internal to a project, and do not necessarily indicate the preferences of the end user or the customer. in the 1980s after the introduction of TQM, a project was consider to be a success by not only meeting the internal performance measure of time, cost and technical specification but also making sure that the project is accepted by the customer; and resulted in customer allowing the contractor to use them as a reference (Švajlenka & Kozlovská, 2018) which is external to the project. The success criteria for a construction project is not only to

evaluate the cost, time and quality as success factors but also to include successful project management, organization success and the customer satisfaction. Reviewing of the relevant literature suggests that different criteria were hypothesized by different researchers (Partnerships, n.d.). These scholars have summarized have summarized ten critical success factory (CSFs) of project though their research. Those CSFs are known as cost, time, quality, satisfaction, management, safety, technology, organization, environment, and resources. But this research is bound to only the first four CSFs so emphasis is given to cost, time, quality, quality, and satisfaction. With the above factors in mind, a range of key performance indicator's (KPIs) to measure the performance of a construction project is developed, both objectively and subjectively.

With reference made to (Lychgate Projects Ltd, 2016) earlier research ,each KPI is discussed practical approaches to measure these KPIs are introduced. The measures of the KPIs in this case only the four criteria are mainly divided into two groups; objective measures (time and cost) and subjective measures (quality and satisfaction). The first group is to use mathematical formula to measure the criteria quantitatively. The other group of criteria is based on subjective opinions and personal judgment. a three to seven –point scale scoring could be applied to measure these KPIs (Waste & Resources Action Programme, 2007).

2.4.2. Objective measures

2.4.2.1. Time

Time is the length of completion of a project.it is planned to enable construction output to be used by the clients future plans (Committee, 2019). From (*MODERN METHODS OF CONSTRUCTION A TECHNIQUE IN ACHIEVING AFFORDABLE HOUSING*, 2017), time can be calculated in terms of construction time speed of construction and time variation .construction time is the absolute time that measures the number of day or weeks from start on site to practical completion of the project. Speed of construction is the relative time, which is defined by gross floor area divided by the construction time. Time variation is measured by the percentage of increase or decrease in the estimated project in

2.4.2.2. Cost

Cost is another importance measure. Cost is defined as the degree to which the general conditions promote the completion of a project within the estimated budget (Miller, 2019). Cost is not only limited to the tender sum only, it is the overall cost that the project acquires from start to end ,so it includes any costs that arise from variations, modification during

construction period ,and the cost created by the legal claims, such as litigation and arbitration. The measure of cost can be in form of unit cost; percentage of net variation over final cost unit cost is a measure or relative cost and is defined by the final contractor sum divided by the gross floor area. Percentage net variation term.it gives an indication of cost overrun or cost under run.

2.4.3. Subjective measures

2.4.3.1. Quality

Quality is another basic that measures success. in the construction industry quality defined as the totality of features required by a product or services to satisfy a given need, fitness for purpose (Office, 2005). Nowadays, quality is the guarantee of the product that persuade the customers or the end users to purchase or use. Specification is one of the criteria that were advocated by (Lovell, 2011). They defined it as the work ship guideline provided to contractors by clients at the beginning of project, the measure of technical specification is to what extent the technical requirements specification is achieved.

2.5. Customer expectation and satisfaction

Customers are those who use the final product/services. Ensuring the completed projects to meet the customer's expectation and satisfaction is essential. (*MODERN METHODS OF CONSTRUCTION A TECHNIQUE IN ACHIEVING AFFORDABLE HOUSING*, 2017) consider satisfied an attribute of success . (B. A. Sheikh & Sharma, 2021) believe that if customers are satisfied, the project can be considered successfully completed in the long run .it is learned from the above statements that measuring the success of a project once its brought to completion is a valuable practice.it provides a learning opportunity for future undertakings, and ,the opportunity to assess the true effectiveness of the project .in order to have a holistic view, objective and subjective criteria need to be considered as mentioned previously (Nathan, 2015).

Project performance and success in therefore measured by the above measure to state whether or not a project has experienced cost overrun or it is within budget, time overrun or it is within schedule, if it is within technical specification or not ,and whether it has satisfied the client or not depending on the project and the measure .it is by these measures that a project manager label the project performance as a success or a failure ,and the effectiveness of MMC on the critical factors of the project objectively and subjectively (Olufemi & Oyedele, 2022).

2.6. Constructions in Ethiopia

Study by (Sarah Payne, 2023) show that, the population of Ethiopia is 120 million and Addis Ababa is about 5 million. From the whole population many people classified as poor. In Africa, Ethiopia is listed as the least urbanized country. Since 1991, Addis Ababa has been known as both by fast economic and population growth. The rapid population growth in Addis Ababa continued to exceed the capacity of low-cost housing for the poor. In Addis Ababa to build low –cost condominium houses in a relatively short time was limited by the rising cost of labour and construction materials and this made it difficult to efficiently address the housing needs of the growing population in a timely manner. As a result of the challenged urban housing policy and strategy was introduced by Ethiopia government. These days the construction of condominium houses has become difficult to be affordable by most of the people and most of time finishing and construction input are poor quality .the study showed that the condominium building in Addis Ababa has failed to meet the housing needs of the poorest of the poor (Waste & Resources Action Programme, 2007).

2.7. Modern method of construction (MMC)

MMC is the term used by the UK to describe offsite technology by moving work from the construction site to factory (Thomas et al., 2022). MMC is new technology in construction industry that improves the requirements of speed, quality and reliability on site .in the main, and these systems are manufactured off-site under a dry roof in factory style condition or by newer on-site technologies. The off-site product is then normally delivered to site by truck and craned into position. The size of the element is often determined by the size of the roads or the difficulties encountered in accessing the site, such as bridges and tunnels (MMC techniques.

UK first found out the manufacturing system from japan through the Toyota perception that builds up the Toyota homes for house manufacturing. The idea has given new significance to the customer in having the both properties made up by Toyota.in 1940s Toyota came out with a new approach on the organization of manufacture, the use of plant, management resources, quality control and relationships between manufactures and users. Identified that approach as the new system of mass production which is more efficient and responsive system and named it as “lean production (Lovell, 2011).

The UK construction industry features has a historically low-level exercising compared with other developed countries. sectors like electricians, joiners and contributing to the increased demand for offsite products .contractors think skills shortage as plumbers were the only trade which they felt was not increasing the demand for offsite to a significant degree .on the other hand, the majority of supplier thought that the lack of concreters, steel erectors and steel fixers contributed little to the increased demand for offsite. The lack of skill would seem perfect for the increased use of offsite but skilled workforce is required to enable innovation such as offsite to be applied (Resom, 2018). Raising the awareness and increasing the perception of offsite, particularly to clients and the general public in order to relieve the technology of its poor historical 'prefab 'image .this could be done by promoting and marketing the benefits and advantages of offsite more widely, both by individual companies and by the government, and by highlighting good practice (Waste & Resources Action Programme, 2007).

Quality control in construction is the practice of making sure that the project is constructed to plan that the completed project meets with the quality standards of the architect engineer, owner, and general contractor. On construction project there are dozens of subcontractors, all of which have specific responsibilities. Supervisors and project manager try to sustain high quality standards but they can't be everywhere at once (Lovell, 2011). The building sector has yet to undergo complete phase of industrialization .yet, if a car was manufacture the way a building is delivered, very few people would be able to be the owner ;if a computer was produced the way a building is delivered ,it would cost a lot of time (Committee, 2019).

Offsite MMCs are prefabrication component or parts of structures, manufactured in factory, then transported and assembled on-set. On-site MMCs are building blocks and parts of structures takes place directly on site. All most all of the good quality products are manufactured in factories around the world. Cars, planes, ships, computers, printers and cell phone are manufactured in factories.in addition; even site-built home use many components that were produced in factories. Modular homes take a shorter time for construction compared with site -built home. this is due to the fact that while the modular is being built in the factory, another crew is building the foundation at the same time(Thomas et al., 2022).

2.8. Adoption of MMC

Many countries are using MMCs on a wider scale, particularly Scandinavia and Germany. Many companies export products/houses made with MMCs, and japan now builds 40% of its

new houses by using MMCs. Many other countries have recognition the benefit of MMCs, but are not widely using them (Sarah Payne, 2023). OSM adoption required fundamental structural changes to the industry and underlined that OSM changes the way people in building industry work, both in term of the process and product (Lovell, 2011). UK is not adopting industrialization in construction and techniques such as offsite construction as it is expected.

The most used offsite type by more UK clients and designers are framing systems, volumetric modular building, cladding systems and bath/toilet/kitchen pods (S. D. Green, 2022b). Factors that drive the growing interest of MMC in UK are an increased demand for housing, mostly in the SE and for low occupancy houses and increasing pressure from government to follow the manufacturing sector, despite its difference to construction. Housing supply in the UK decreased since WW2 and shortage in housing supply is limiting economic growth, restricting access to housing and affecting the distribution of wealth within the society (Nathan, 2015).

In Nigeria projects are not properly planned and it leading to unknown project time and terminated projects. Nigeria is in immature stage of adopting MMC at medium and small scale construction, but the large construction companies are showing sign of adoption of the concept .clay and timber are plentiful in Nigeria which uses as MMC to solve housing problem ,but Nigerians have refused to accept these materials as a means of their construction (Olufemi & Oyedele, 2022).there is a housing problem in Nigeria and it is caused by number of factory such as high population growth ,skill shortage and unwillingness to accept new construction practice .

In Malaysia, the IBS (industrialized building system) was introduced in 1964 by the housing and government after making reference to the accomplishment of different European countries. Ever since 1998 people in Malaysia started to accept IBS over the traditional method as a result of awareness program the construction industry development board (CIDB) on the benefits of IBS. form early 1960s to 2010 IBS components have evolved from frame system, panel system and box system to pre –cast concrete systems, formwork systems and framing systems prefabricated timber framing system, block work systems and innovative. Mostly used IBS component in Malaysia are pre-cast concrete systems and formworks systems (Resom, 2018).

Modern method of construction is on way to achieve sustainable construction. Sustainable construction in Slovakia divided into economic ,environmental and social.it most be supported by appropriate method of construction ,construction material within the sustainable design and

management of construction .according to (Miller, 2019) MMC adoption for building is motivated by demands for faster construction ,skills shortage and sustainability of construction investors in Slovakia Are frequently working for the development of new and better building materials based on the conventional principle because of the public attitude to use nature materials .the investors still do not favour the sustainable natural construction materials but proven known methods and technologies. Consequently, the construction market is not required for the development of construction skill and professionals dealing with using of tradition materials by modern method of construction (Office, 2005).

2.9. MMC experience on different countries

2.9.1. China

MMC is known in china as industrialized building (IB).it is agreed through many research that IB have a main role within the Chinese residential development.it improve quality, productivity, cost-effectiveness ,safety and sustainability (Rushton, 2022). However, the application of prefabricated construction was found restricted due to the lack of understanding the potential benefits of pre-fabricated houses. The challenges of the prefabrication technology in china were persistently mentioned. The main challenges included lack of manufacturing capability, product quality problems and lack of supply chain (Tara Flynn, 2022). The competences of MMCs are justified by recent example from china a 15-story hotel was built in china in just one week and another prefabricated 30-story tower was erected in just two weeks (Sarah Payne, 2023).

2.9.2. India

In India, a growing demand for housing was reported. The projected demand was nearly 27 million houses required by 2012. It was noted that 99% of those houses were needed by households within the lower income group. Therefore, the Indian government and construction manufacturing industries embraced a larger volume of housing production with good quality. India has established prefabricated and modular technologies in its construction sector. The India concept house (ICH) represents construction of affordable housing using prefabricated technology (B. A. Sheikh, 2021).

ICH is considered as an innovative prefabricated housing solution that could help to achieve cost savings and reduce construction time by 90%.the prefabricated building system enables a 23 square meter house to be built in four weeks and 93 square meter house to be built in sex

weeks. The ICH conceives as both a dwelling for inhabitation and as a process by which houses are produced through a managed supply chain. ICH designed as 23, 46, 70 and 93 square meter increments that facilitating expansion from one room to four rooms. The prefabricated houses are generally considered as cost effective quick to assemble and sustainable. However, the maturity of prefabricated technology was found to be steadily developing .it was suggested that the improvement to prefabrication maturity should including the whole supply chain of prefabricated house building (Sardén & Engström, 2010).

2.9.3. Malaysia

The researcher found that the prefabricated house building in Malaysia has reached market maturity. The Malaysia government has accepted the industrialized building systems (IBS)bin the housing projects to improve delivery timing ,and producing affordable and quality houses (Sarah Payne, 2023). Besides adopting IBS, the government has well established IBS legislation and building code to improve the uptake of high quality prefabricated houses for the construction sector. Never the less, supply chain system was urged to take care of the competency of future house building supply (B. A. Sheikh, 2021).

2.9.4. Tanzania

(Olufemi & Oyedele, 2022) stated that prefabricated houses are still in immature state in east African countries. (Richard Valentine Selsey, Kevin Mofid, 2020)studied the advantage of applying semi-prefabricated concrete construction methods in the Tanzanian housing industry. The stressed benefits including saving of up to 19 % of direct total cost and reducing construction time up to 57%. The idea of prefabricated house building started in Dodoma, the capital of Tanzania, in 2013.the capital development authority was responsible of planning and development. This conceptual idea expected to deliver many low-cost houses within a short period. Future studies on this project may shade new light to Tanzanian housing growth and house quality development

2.9.5. Egypt

The Egyptian housing sector has been experiencing a scarcity of providing affordable houses for the low –income group of population. The central agency for public mobilization and statistics (CAPMAS) reported shortage of around 40,000 houses annually (Švajlenka & Kozlovská, 2018). The factors contributing to the situation can be classified into economic, legislative, social and construction method. Although there is major concern over the housing situation, the combined efforts of both public and construction projects sector have struggled

to meet the growing demand. Addressing the shortage situation by suggesting new construction method and building materials were found to be minimal. The MMC in the Egyptian context only limited to caravan offices or precast concrete. The market of prefab is merely producing temporary offices and caravan for the major infrastructure projects or precast building (Olufemi & Oyedele, 2022).

2.9.6. Nigeria

(Olufemi & Oyedele, 2022) stated that the OSM in Nigeria still gradually developing based on learning from other developed countries. They stressed the core OSM up take barriers in Nigeria including reluctance to innovate, small number of code and standards, supply chain integrations, and skill requirements.to address these barriers, governmental support is an essential in helping to establish OSM as a practical substitute to traditional methods. They observed the need to encourage the awareness of OSM should be through better government policies and through skilled supply chain partners.

2.9.7. Saudi Arabia

The awareness of prefabrication technology was positive in the construction sector within Saudi Arabia. the prefabrication technologies were found limited to concert components.it was only applied in building bridges, wall and front panels for multi-storey buildings, and temporary structure such as site offices and portable toilets. The idea of prefabrication was not well accepted as an important part of construction processes. The development of manufacturing sector and the upgrade of construction –related –manufacturing were considered as possible ways of increasing the adoption of prefabrication technology in Saudi Arabia (Ali & Al-Zaid, 2022).

2.10. Modern Method of Construction in Ethiopia

According to many countries experience, MMCs is nowadays practicing on a wider scale. As agreed by many scholars, MMC also results in a more reliable construction project scheduling, delivery, and reducing duration of projects due the amount of time spent on site relies on the amount of factory produced components and those traditionally produced. Construction time on average is affected by material shortage, skill shortage and bad weather conditions. In the case of MMC, these problems have been addressed because most of the building components are manufactured in factories and transported to site; this reduces the amount of time spent on

site. As a result of the short time spent on site, it is easier to predict completion date. Most of the interviewees also agreed on the above effectiveness measures (Abebe, 2020).

The findings of this study show the relationship between MMC implementation effectiveness on time and the contractors that had experienced the highest delay in percentage. It is mentioned above that the contractors that had experienced the most project time overrun are contractor no.2 and contractor no.3. Both contractor no. 2 and 3 are indifferent to most of the effectiveness level measures of project time, in relation to MMC implementation. Contractor no.2 even disagrees that MMC implementation leads to better performance. These contractors said that they have not gained tangible benefits from implementing MMC because in Ethiopia importing goods is somewhat always time taking process during freight.

The most used offsite type by more Ethiopian clients and designers are framing systems, volumetric modular building, cladding systems and bath/toilet/kitchen pods (Abebe, 2020). Factors that drive the growing interest of MMC in Ethiopia are an increased demand for housing, mostly in the SE and for low occupancy houses and increasing pressure from government to follow the manufacturing sector, despite its difference to construction.

2.11. MMC initiatives

Clients and designers think that it is the client who usually drives the use of offsite on a project, together with the contractor, designer and architect. on the other hand, contractor feel that it is more themselves and the architect who are the drivers. Suppliers on the other hand, think they themselves are one of the drivers, together with the client and the contractor and that the designer and architecture less so. Supplier think that the take –up of offsite is highly influenced by client's resistance to offsite (Sanna, 2018).

The main method to overcome client's resistance is provision of example and case studies of previous successful uses of offsite. the other main methods including client experience and increased partnership and marketing, all different ways of informing, educating and/or convincing the client of the possibilities and advantage of offsite. Cost reduction in MMC products were only used by less than half of the suppliers in the survey, even though the increased expense of offsite was the main barrier to use mentioned by client/designer and contractor? More than half of the suppliers possibly sold the use of offsite on other factors like speed of construction, quality, and value rather than cost (Committee, 2019).

2.12. Advantage of MMC

(Lovell, 2011) belief that MMC in the construction industry has improved efficiency and better quality as well as several benefits as reduced construction time, lower overall construction cost enhanced durability, better architectural appearance, enhanced occupational health and safety, material protection, less construction site waste, less environmental emissions, and reduction of energy and water consumption. Main barriers hindering the increased use of offsite are the belief that using offsite is more expensive. Even though offsite is known for its reduced initial cost and reduced whole life cost suppliers often argue that offsite is not compared in the right manner in order to take into account advantage such as reduced onsite construction time and economies of scale.

The major benefit of offsite compared with traditional construction is thought to be the reduced construction time on site followed by increased quality, more consistent product, reduced snagging& defects, increased value, increased sustainability, reduced initial cost and reduced whole life cost (Olufemi & Oyedele, 2022), offsite manufacture removes much of the construction process from the construction site ,leading to several efficiency, productivity and environmental benefits. These include; reduced onsite labour, save weeks on project times, reducing overheads, better ROI for clients, less waste, less material used, less onsite faults, better health and safety and more environmentally friendly (Sarah Payne, 2023). Successful implementation MMC in construction industry can offer different benefits compared to conventional in-situ systems.

High speed of construction, cost savings, reduction of unskilled workers, faster and better-quality control of construction are the significant advantages of IBS. Literatures on the use of offsite construction in Nigeria (Olufemi & Oyedele, 2022) and in (Lovell, 2011) show that offsite construction has several advantages:

Time

The application of MMC on site reduced time for construction and consequent product delivery. The over time spent on site usually depends on the material produced on –site and offsite and it is mainly affected by the material delivered ,skilled man power and weather condition .in offsite construction most of the components are manufactured in factory and assembled on site ,this will minimize the amount of time spent on site (Švajlenka & Kozlovská,

2018). Suggested that for minimizing delay in project is to reduce the change in drawing during the construction. In Pakistan delay occur in large construction projects because of the change of government due to which construction is stopped and new government propose new design for construction as well as bill are not easily passed by new government.

Quality

The exact definition of quality differed slightly from person to person, but they remained in two basic categories: conformance to requirements; and customer satisfaction (Olufemi & Oyedele, 2022). It is easier to control quality at the factory than on-site and better quality in the manufacturing components and less error will be experienced with improve product consistency and easier quality control at factory. MMC improves the three requirements of quality; durability, whole life cost and performance.

Cost

MMC thought to be expensive than on-site production, but it reduces life cycle cost, better quality building which in turn reduce maintenance cost, reduction of waste and reduction of overhead costs. MMC can be achieved in the areas of cost assurance and minimize risk, less overall lifecycle costs, better quality of building which will in –turn lead to reduced maintenance cost, reduced preliminaries and site overhead, reduced construction time which can result in cost benefit from early occupation of the property (Sarah Payne, 2023).

2.12.1. Environmental sustainability

MMC reduces building and on -site wastes up to 40% of the land fill and reduce waste on the construction site and environmental pollution during construction (Švajlenka & Kozlovská, 2018).

2.12.2. Logistics and site operation

MMC help construction with limited access and working space such as airports, prisons, roads and rail projects since it reduces the amount of time spent by the contractors (Thomas et al., 2022).

2.13. Limitation of using MMC

Study on engineering and managerial department about barriers of implementing and adoption MMC in UK and china found out different barriers. Inflexibility to late design change, higher

initial cost, higher overall cost, and incompetency for small project and higher cost for long distance transportation are the top five barriers (Ali & Al-Zaid, 2022). The author discussed ,even though the study was conducted only in UK and china the research questions and objectives were supported on a broad literature review.it was suggested that the study may also be extended to other economies, with modification to suit country –specific circumstances and conditions, which may be identified through the use of the same or similar research instruments (Olufemi & Oyedele, 2022). MMC has been believed as one of the most effective methods, but the construction industry has found difficulties implementing it.

Factories that produced components and modules for MMCs involve high start-up costs to set up suitable machinery and a prefabrication yard for the production of the components and modules. They also need to purchase all applicable materials at the start of the project which leads to higher initial costs. Moreover, the majority of factory over heading costs such as labour are fixed, not considering of production. The construction cost per unit becomes high if precast components are of small quantities.in contrast, many site –based overhead costs are only incurred if construction takes place (Thomas et al., 2022).

Therefore, it is not easy to use MMCs to respond to variable demand. These lead to MMCs with higher initial costs and potentially higher overall costs than traditional methods. MMC in some companies considered to be higher initial cost, they argue that saving on –site are not taken into account in financial models and others had been unable to accomplish major saving to counter the higher initial costs (Kyjaková & Bašková, n.d.). Some companies are afraid to take risks by using new approach and the result on cost, labour needed, site problem and most client's reaction to wards MMC application (Lovell, 2011). MMC is considered to be standard or repetitive design and early fixation of design needed which limit the construction industry to make changes (Sarah Payne, 2023). Transportation is seen as one limitation and adding cost since transportation large unit material to site might be difficult and costly (Lovell, 2011). Lack of understanding and skills to install the component is seen as another limitation of using MMC (B. A. Sheikh & Sharma, 2021).

2.14. Research Gap

Construction projects are notorious for cost overruns and delays in project completion. Over the past three decades, globalization and competition have become increasingly fierce. therefore, globalization and competition are the most important reasons every construction

company needs to improve and calibrate its system to achieve its goals with management tools. Several reports have criticized the construction industry, especially in terms of productivity, quality and quality systems, and most project managers focus on cost and time rather than the quality of the project. construction, but the researchers emphasize that more attention should be paid to quality. Many project in developing countries face considerable time and cost over runs ,fail to fill their proposed aim or even totally terminated and abandoned before or after their completion. Moreover, the progress of the construction industry in developing countries generally lags far behind from other industries in those countries in those countries and their counterparts in developed nations. The construction industry in developing countries failed to meet expectations of governments, clients and society.

According to the literature review made, Modern method of construction is important and emerging to be used throughout the world. However, as of its importance it does not get enough emphasis in Ethiopia. What is MMC, how it is applicable, how it is practicing, what it demands as compared to conventional construction method, its advantage and dis advantage have not been studied so far. Therefore, in this study the MMC in Addis Ababa construction projects, the case in selected public building projects.

CHAPTER THREE

3. RESEARCH METHODOLOGY

Research methodology is defined as a science of studying how research is done systematically, it helps to solve research problem. Methodology shows how problem are studied, what information are collected using which methods, and how information is analysed to arrive at the conclusions and to develop recommendation (Simachew, 2019).

3.1. Study area

This study was made on selected projects in Addis Ababa. The map location of Addis Ababa is shown in Figure 3.1.

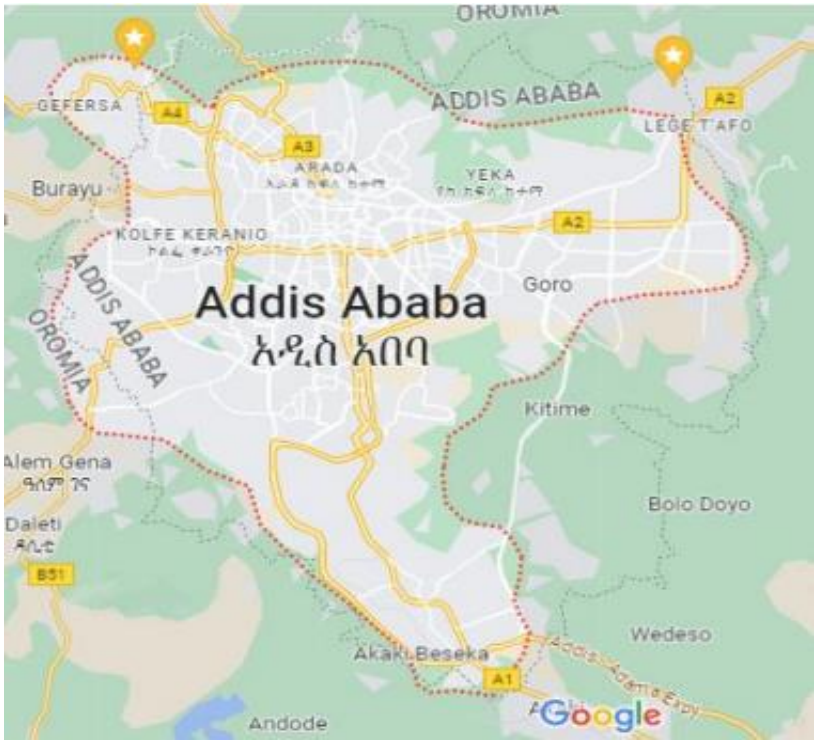

Figure 3.1 Location Map of Addis Ababa

3.2. Research design and Approach

3.2.1. Research Designs

Descriptive and exploratory research designs was used in this study. The exploratory type concerned on gaining idea and insight about the MMC of selected construction projects in Addis Ababa. And the descriptive type describes the extent of the works and practices of MMC

of construction projects in Addis Ababa. The research was conducted through structured questionnaires and interviews. In order to get appropriate information, the researcher used survey as the population is large in number and there exist financial and time limitations to conduct. The sample was taken randomly.

3.2.2. Research Approach

Research approaches can be categorized as either quantitative or qualitative. quantitative data includes close-ended information such as that found to measure attitudes, behaviours, and performance instruments. The analysis of this type of data consists of statistically analysing scores collected on instruments like questionnaires or checklists to answer research questions or to test hypotheses. On the other hand, qualitative data consists of open-ended information that the researcher usually gathers through interviews, focus group and observation. the analysis of the qualitative data typically follows the path of aggregating in into categories of information and presenting the diversity of ideas gathered during data collection (Moore, 2019).

This research used both quantitative and qualitative approaches. This is because, it is needed to explore the practices and experiences of MMC in-depth. It also helps to investigate the efficiency of MMC in the study area. While qualitative study is better to describe and analyse small sample units, quantitative study is important to investigate high number of samples difficult to manage using quantitative study (Tiumelissan & Pankhurst, 2013).

3.3. Population of the Research

This research paper concentrates on MMC construction projects in Addis Ababa. This focuses on the main participant stakeholders of the construction projects. It includes the client, the contractor and the consultant. Respondents of the survey data were therefore, staffs of these stakeholders.

Table 3.1 population of the research

No.	Name of stakeholder	Number Stakeholders
1	Client	80
2	Contractor	288
3	Consultant	15
4	Total	383

Source, Addis Ababa Construction Bureau (2023)

3.4. Sample size and sampling technique

3.4.1. Sample Size

The required sample size for the research for each party involved in the survey was determined statistically using solven's sample size formula as shown in Equation 3.1.

no=p*q/v2

n= no / [1+ (no /N)]

where:

- no: First estimate of sample size
- p: The proportion of the characteristic being measured in the target population
- q: Complement of p or 1-p
- v: The maximum standard error allowed (10% for our case)
- n: sample size for the study
- N: population of the study

Accordingly, the sample size of each of the stakeholders is calculated as follows.

Client

Given: N=80, p=0.5, q=0.5, v=0.1

no=0.5*0.5/0.1^2=25

n=25/ (1+25/80) =19

Contractor

Given: N=288, p=0.5, q=0.5, v=0.1

no=0.5*0.5/0.1^2=25

n=25/ (1+25/288) =23

Consultant

Given: N=15, p=0.5, q=0.5, v=0.1

no=0.5*0.5/0.1^2=25

n=25/ (1+25/15) =9

Total sample size=19+23+9=51

3.4.2. Sampling Technique

Sampling involves the selection of a number of study units from a defined study population. The population is too large for us to consider collecting information from all its members. Instead we select a sample of individuals hoping that the sample is representative of the population. Data analysts can use probability data sampling methods. Probability methods use random number that match with points in the data set to ensure that there is no relationship between point in the data set to ensure that there is no relationship between points chosen for the sample. non-probability data sampling methods include convenience sampling, consecutive sampling, purposive (judgmental) sampling and quota sampling. Purposive or judgmental sampling is when the researcher selects the data to sample based on predefined criteria.

According to (Simachew, 2019), a population is a group of items that a sample will draw. A sample, on the other hand, refers to a set of individuals selected from an identified population with the intent of generalizing the findings to the entire population. A sample is drawn as a result of constraints that make it difficult to cover the entire research population (Bantayehu, 2021).

Based on this concept, in this study we use stratified random sampling and purposive sampling strategies to include for qualitative and quantitative studies to get the particular target population. The random sampling technique is used to select projects. While purposive sampling technique is used to select respondents from the selected construction projects. In this context the target populations are those stated in section 3.3 of this paper.

3.5. Method of data collection

Two types of data were collected for this research. Primary data and secondary. Primary data was collected in the form of structured questionnaires and semi-structured interview questions to the randomly and purposively selected respondents. And the secondary data was found by referring books, journals, and articles that can back up the MMC implementation practices around the world. Questionnaires and interview were chosen to address the questions of the

research in- depth. And clarification was given to all respondents of the questionnaire in order to minimize bias on the survey data.

3.6. Steps of data collection

In this research, Literatures are reviewed first. Literature was reviewed and questionnaire variables was identified. On the process of literature review, it was assessed the back ground of MMC, practices of MMC and techniques of MMC. After reviewing relevant documents questionnaires and interviews have been designed. Structured questionnaires and interviews were designed in a way to achieve the research objectives. Copies of these questionnaires and interviews are attached in the appendix part of this paper. The data for this research was collected by distributing a formulated structured questionnaire and interviews as asked in a structured way. The data that was collected from questionnaires and interview was analyzed both qualitatively and quantitatively. Tables and graphs were employed for elaborating and discussing the data. After the analysis made, Conclusion was drawn from the bases of the analysis and recommendation was forwarded to the user of this research regarding to MMC practices and techniques.

3.7. Method of data analysis and data presentation

3.7.1. Quantitative data analysis method

The data collected was analyzed and presented in tables, percentage, frequency and figures. In addition to this, reliability and validity teste were used to testify the significance of results obtained from the respondents and to identify the effects of gender, age, education, job position, and experience of the respondents with the help of Statistical Package computer software package SPSS (Statistical Package for Social Science) version -20. Data obtained from observation, experience, interviews and secondary sources were also used to strengthen the overall understanding of the issue.

3.7.2. Qualitative data analysis methods

Several methods are available to analyse qualitative data the most commonly used data analysis methods are

Content analysis: it is often one among the foremost methods to study qualitative data .it is use to study documented information within the sort of text, media, or may be physical items.

When to use this method depends on the research question. Content analysis is usually used to study Reponses from interviewees.

Narrative analysis: this method is used to study content from various sources, such as selected personnel interviews, observation from the field, or surveys .it focuses on using stories and understanding of people interviewed to answer the research question.

Discourse analysis: this method is like narrative analysis but it studies interaction with people. However, it focuses on analysing the social context during which the communication between the researcher and the respondent occurred.it also uses information that the researcher get by looking at the respondents day-to-day environment.

Grounded theory; it uses qualitative data analysis to describe why a certain phenomenon happened. It does this by reviewing different situation and using the data to develop causal justification .researchers may changes the justifications or create new ones as they study more cases until they arrive at an explanation that fits all cases.by studying the above methods of analysis, this research, narrative analysis is used for the semi structured interview data. The collected data from the interview questions by the selected contractors are gathered and analysed by comparing and contrasting the interview stories.

Then the connection between the answers and the previous studies are narrowed to easily present the findings. Since it is qualitative, all data retrieved through interview may vary in content, but the categorization will help to generalize the findings. Then, a summary of each data is organized from the data collected and presented that show the analysis of the MMC practices implemented by the contractors to have maximum effectiveness on their construction projects are developed.

3.8. Validity and reliability

3.8.1. Validity

Validity is a term used to evaluate the accuracy and quality of research. It is related to how a method; a technique and tests of a research are accurate. To increase the validity of the research, the researcher was undertaking the following conditions:

1) Data was collected using standardized interview and questionnaire. 2) Sample questionnaire was distributed and collected by the researcher carefully and 3) a pilot test by experienced professionals with an experience of more than 25 years in road construction areas on those who

are working around the case study area will be conducted. Through having comments from those professionals, the validity of questions will be confirmed.

Table 3.2 Results of validity for reliability test

Case Processing Summary			
		N	%
Cases	Valid	10	100.0
	Excluded[a]	0	.0
	Total	10	100.0
a. Listwise deletion based on all variables in the procedure.			

Source, SPSS generated from own survey (2023)

3.8.2. Reliability

Reliability is a consistency of a measurement. It has to do with the accuracy and precision of a measurement procedure. The questionnaire was pre-tested with few employees to test the content of the instrument and also to check the clarity, ambiguity structure and length before the final distribution of the questionnaire.

Table 3.3 Reliability test result

Reliability Statistics	
Cronbach's Alpha	N of Items
.893	10

3.9. Ethical consideration

The researcher declares that, all the information given by respondents kept confidentially without disclosing the respondents' identity and respect the valuable relationship among them. In addition to this, the questionnaire was distributed only to voluntary participants and interviews will be asked to voluntary participants. Lastly, all secondary quoted to keep the right of ownership of all materials.

CHAPTER FOUR

4. RESULTS AND DISCUSSION

4.1. Introduction

This chapter deals with the presentation and analysis of data. The data were obtained from primary and secondary sources. In addition to that the data obtained from primary source were gathered through questionnaires and observation. The secondary sources of data were gathered from relevant documents and archived files. This document analysis has been used to gather information with regard to Modern Methods of Construction. This study made use of descriptive statistics using frequencies both on single and multiple response questions. In multiple response questions, the study used Likert scale in collecting the data. The data analysis and findings were presented in the form of tables and graphs as appropriate for explanations and interpretation in line with the research objectives. A total of 51 questionnaires were distributed to randomly selected construction projects. Out of the 48 questionnaires, only 43 (84.3%) were fully accepted as suitable for the analysis purpose. On the other hand, 5 questionnaires were not returned, and the remaining 3 questionnaires were retrieved with the majority (>50%) of the questions unanswered.

4.2. Background Information of Respondents

This section provides the general personal information and the background of the respondents who were involved in the study including Gender of respondent, age of respondent, occupation of respondents, and experience of respondents is described as follows:

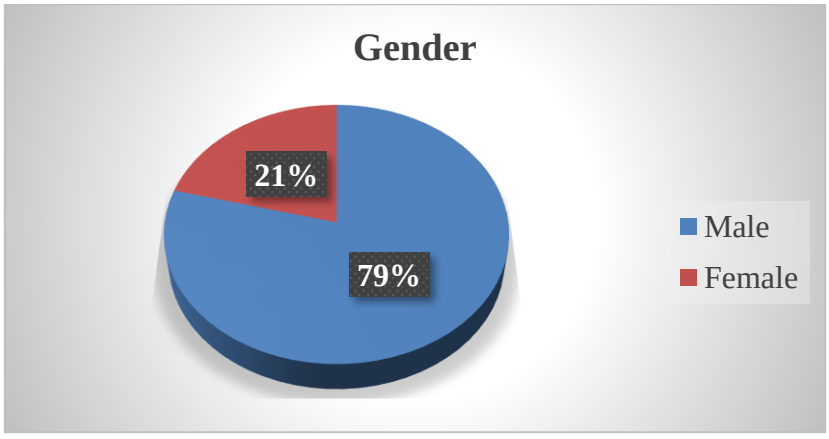

Figure 4.1 Gender of respondents

Source, own survey (2023)

Based on the survey data as shown in Figure 4.1, 795 of the respondents were males and the remaining 21% respondents were females.

Regarding the age of the respondents as indicated in Figure 4.2, 195 of the respondents were between 18 and 25 years old, 35% of the respondents were between 26 and 35 years old, and 30% of the respondents were between 36 and 45 years. The remaining 16% of the repondents were 46 and above years old.

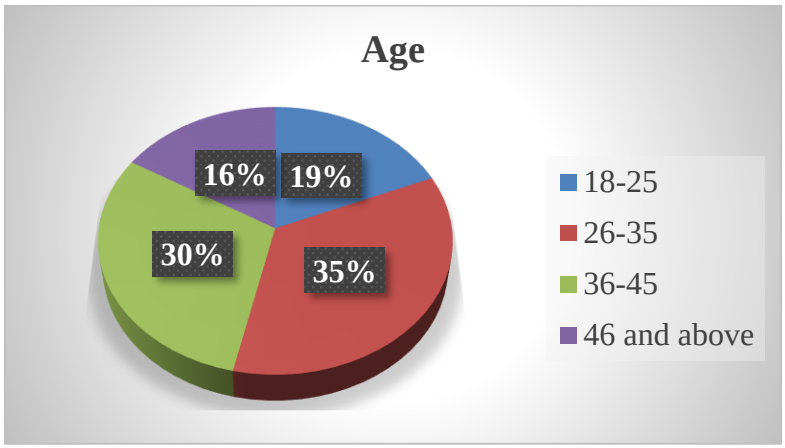

Figure 4.2 Age of respondents

Source, own survey (2023)

In the survey questionnaire, the occupation of the respondents was asked and the following data was gathered as labelled in Figure 4.3. majority of the respondents were site engineers (30% of the respondents). 16% of the respondents were government officials, 19% of the respondents were formans, 12% of the respondents were project managers and 23% of the respondents were resident engineers.

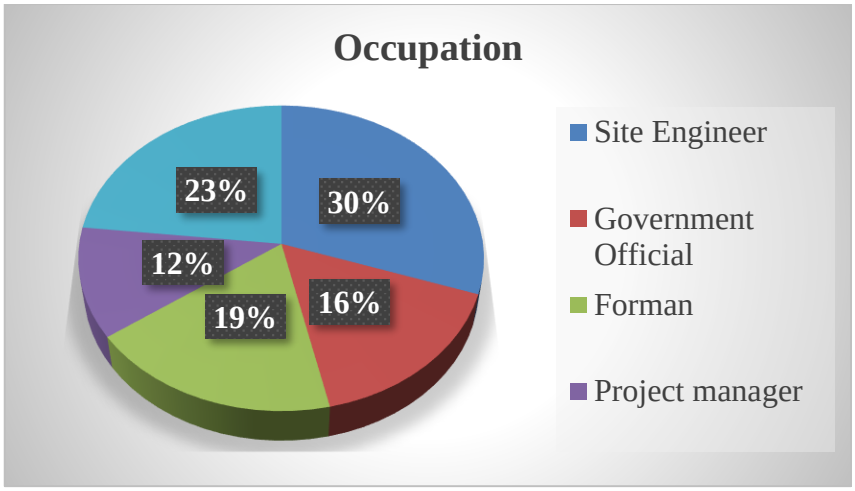

Figure 4.3 Occupation of respondents

Source, own survey (2023)

35% of the respondents had a work experience of 15 years and above. Out of the survey respondents, the 30% had an experience of between 10 and 15 years of experience. 23% of the respondents and 12% of the respondents had an experience between 5 and 10 years and less than 5 years respectively. From this it can be understand that, the respondents can understand the questionnaire and can provide relevant information for the researcher.

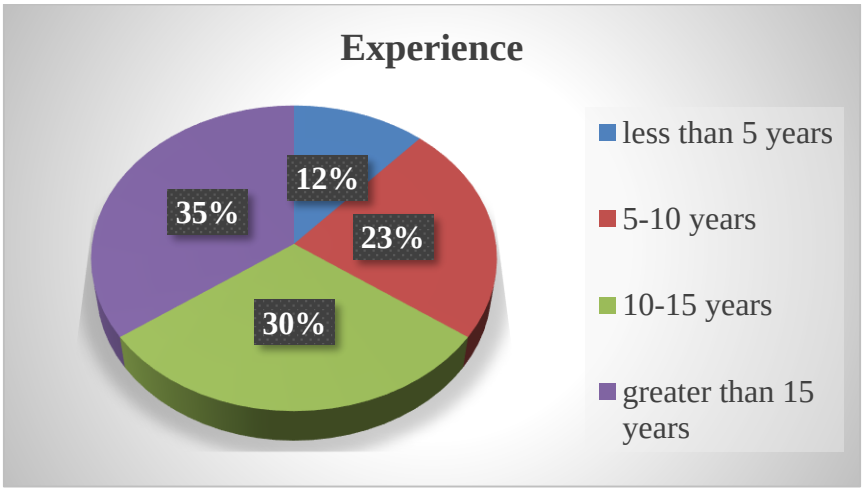

Figure 4.4 Experience of respondents

Source, own survey (2023)

4.3. Efficient MMC types and methods of practice

To discuss and survey on MMC, the respondents should have basic information about MMC. Therefore, an assessment was made on the awareness of the respondents as shown in Table 4.1.

accordingly, for the survey question ‘I am familiar with the concept of Modern Method of Construction’, 40% of the respondents strongly dis agree and 23% of the respondents dis agree. From this it can be said that, over 63% of the respondents had no awareness of MMC. 21% of the respondents chose no comment (being neutral). The agreement of the remaining 7% of the respondents and 9% of the respondents is strongly agree and agree. This means only few personnels have a concept about MMC.

Regarding the understanding of the respondents on MMC, for the survey question ‘I have adequate knowledge about the benefits of using Modern Method of Construction’, the response of 47% of the respondents is strongly dis agree and the response of 30% of the repondents is dis agree. This shows that most of the workers of construction industries have not adequate knowledge regarding the benefits and using MMC. On the other side, the response of 9% of the respondents and the response of 7% of the respondents is agree and strongly agree. The workers with adequate knowledge about MMC is few in number according to the survey results shown in Table 4.1. 7% of the respondents prefers neutral to neither agree nor dis agree.

For the survey question ‘I understand the construction process involved in Modern Method of Construction’, the opinion of 42% of the respondents is strongly dis agree, and the opinion of 30% of the respondents is dis agree. From this it can be said that the workers of the construction companies do not understand the process of MMC. In reverse, the opinion of 7% of the respondents and the opinion of9% of the respondents is agree and strongly agree. These workers have a good understanding of MMC. This is because only few numbers of worker are required to facilitate the MMC process. The remaining workers are allowed to work on the conventional method.

Table 4.1 Knowledge of respondents on MMC

No.	Knowledge on MMC	Strongly dis agree	Dis agree	Neutral	Agree	Strongly agree	Total
1	I am familiar with the concept of Modern Method of Construction	17	10	9	4	3	43
		40%	23%	21%	9%	7%	100%
2		20	13	3	4	3	43

	I have adequate knowledge about the benefits of using Modern Method of Construction	47%	30%	7%	9%	7%	100%
3	I understand the construction process involved in Modern Method of Construction	18	13	5	3	4	43
		42%	30%	12%	7%	9%	100%

Source, own survey (2023)

According to the study made by (Momoh, 2022), knowledge of MMC of workers of construction industry is very important for the following reasons. 1) Faster Construction: The method of delivery in comparison to the traditional brick and mortar method of construction has an obvious benefit concerning the construction time. 2) Increase in the number of homes delivered: With the various systems available MMC offers the ability to build custom/self-built homes and affordable mass housing. 3) Market Absorption for innovative designs: MMC creates an opportunity to introduce innovative designs. Its offers alternative products to the market in comparison to the traditional method that is rigid. 4) MMC can reduce construction impacts: It creates an opportunity to carry out construction in small restricted areas, infill sites and city centres. 5) MMC offers high building standards: The method of production of housing is within a controlled factory environment with high precision engineering. 6) Design flexibility to solve every size and scale of project: MMC offers a broad range of design options available means that materials, massing and design details can be designed to the site and the local vernacular. 7) Reduction in energy consumption, site construction risks and fewer deliveries to the site: Due to composite production of building fewer materials are sent to the site.

Efficient utilization of MMC can have many advantages over the conventional method of construction. This includes cost, time, quality, safety, energy efficient, flexibility in construction and design, and sustainability. Survey data was collected from repondents as presented in Table 4.2.

The response of 5% of the respondents strongly dis agree and the response of 7% of respondents is dis agree in response of the survey questionnaire ‘Reduces construction time compared to traditional construction methods’ asked. Only few numbers of the respondents do not believe

that MMC in reduction of time as compared to traditional construction methods. On the other hand, the opinion of 30% of the respondents agree and 51% of the respondents strongly agree. This indicates that, MMC contributes a remarkable effect on reducing construction time as shown in Table 4.2. Only 7% of the respondents neither agree nor dis agree. They declined to comment (being neutral). This can show that these respondents do not have any information about MMC.

Table 4.2 Efficiency of Modern Method of Construction

No.	Efficiency of MMC	Strongly dis agree	Dis agree	Neutral	Agree	Strongly agree	RII	
1	Reduces construction time compared to traditional construction methods	5%	7%	7%	30%	51%	0.83	83%
2	Enhances the overall quality of construction projects	5%	7%	7%	28%	53%	0.84	84%
3	Reduces construction costs	7%	12%	14%	21%	47%	0.78	78%
4	Improves construction site safety	14%	12%	19%	26%	30%	0.69	69%
5	Results in better energy efficiency in buildings	12%	14%	16%	28%	30%	0.70	70%
6	Better architectural flexibility and design options	5%	12%	12%	14%	58%	0.82	82%
7	The availability of training and education for workers is adequate in Addis Ababa	9%	7%	19%	33%	33%	0.74	74%
8	Improves construction efficiency and reduces project timelines	7%	5%	12%	21%	56%	0.83	83%
9	Enhances the overall quality and durability of buildings	5%	7%	9%	26%	53%	0.83	83%
10	Promotes sustainable and eco-friendly construction practices	7%	5%	21%	26%	42%	78%	0.781395

Source, own survey (2023)

As shown in Table 4.2, most of the respondents agreed with the efficiency of MMC to minimize project time, total cost of projects, it has better flexibility, promotes sustainable and eco-

friendly construction practices, enhances the overall quality of construction projects, results in better energy efficiency in buildings, and improves construction efficiency and reduces project timelines.

Efficient method of MMC shows more enhancements as compared to conventional construction methods as indicated by (Tara Flynn, 2022). 1) Process and lifecycle improvement: Due to various uncertainty experienced within most construction projects, there is a delay in delivery of the overall project and this can be easily managed using MMC. 2) Cost/Value and productivity MMC is perceived to be more expensive than the traditional method of construction. But research conducted alongside the current cost of homes stipulates that MMC can be used to achieve cost savings and reduced risk over the entire lifecycle. 3) Quality Improvement: The context has witnessed a poor level of housing construction over the year and MMC is perceived as a method in producing high standard quality homes. 4) Improved Logistics and Site Operation with the current housing deficit in Nigeria, it is paramount to produce houses at a faster pace ensuring quality is introduced and efficacy in the overall construction delivery.

4.4. Impact of MMC in study area

As compared to conventional method of construction, MMC offers improved project efficiency. According to the survey data collected presented in Figure 4.5, 37% of the respondents strongly agree and 33% of the respondents agree to the survey question ‘Modern methods of construction (MMC) offer improved project efficiency and faster completion times’, while 12% of the respondents were neutral. As it is indicated the majority of the respondents agreed. This shows MMC offers improved efficiency in construction projects as compared to conventional method of construction. Only 12% of the respondents strongly dis agree and 7% dis agree on the idea. These respondents may be those who do not have concept on MMC.

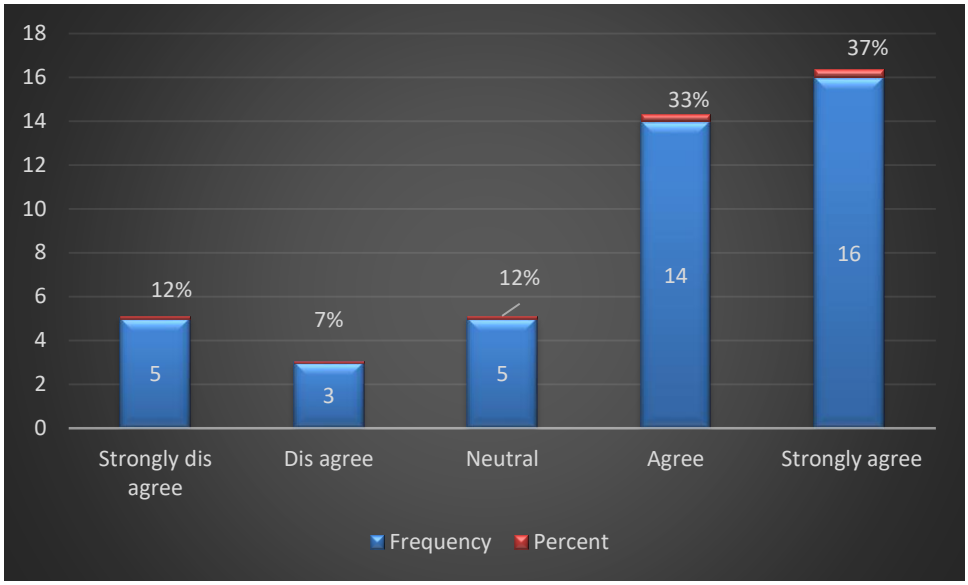

Figure 4.5 Modern methods of construction (MMC) offer improved project efficiency and faster completion times

Source, own survey (2023)

In response to the survey questionnaire 'MMC techniques lead to higher quality construction outcomes compared to traditional methods', 47% of the respondents strongly agree, and 28% of the respondents agree. This shows quality of construction projects accepts the techniques of MMC to foster quality of construction products prefer to traditional method of construction. The response of 14% of the respondents is neutral. This shows that the respondents do not know MMC or their organization do not use MMC.

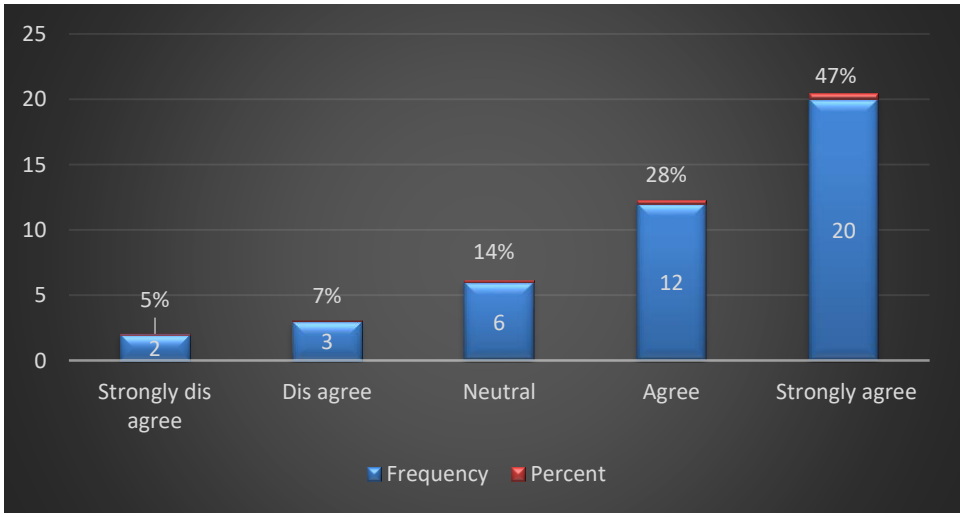

Figure 4.6 MMC techniques lead to higher quality construction outcomes compared to traditional methods

Source, own survey (2023)

The response of the remaining 5% of the respondents and the response of 7% of the respondents is strongly dis agree and dis agree respectively. These respondents believe that MMC techniques are difficult. If the MMC is not handled by well experienced workers, its risks are greater than its benefits. Defective works may be caused if the worker is not well experienced of MMC. The data is presented in Figure 4.6.

Construction works using traditional method can cause different effects on the environment. This can include sound prolusion, dust pollution, waste disposal. Even traditional construction is difficult for environmental crowding. This is because construction materials are disposed on site by closing roads, walkways. However, if MMC is used these effects may be minimized. According to the survey data as presented in Figure 4.7, 33% of the respondents strongly agree and 30% of the respondents agree in response of the survey questionnaire 'The implementation of MMC reduces the environmental impact of construction projects' assessed. This indicates if MMC is used for the production of construction products, the environmental impact of construction work is reduced. The reduction of environmental impact may include noise reduction, reduction of road crowding, minimization of safety and even health issues to be caused as a result.

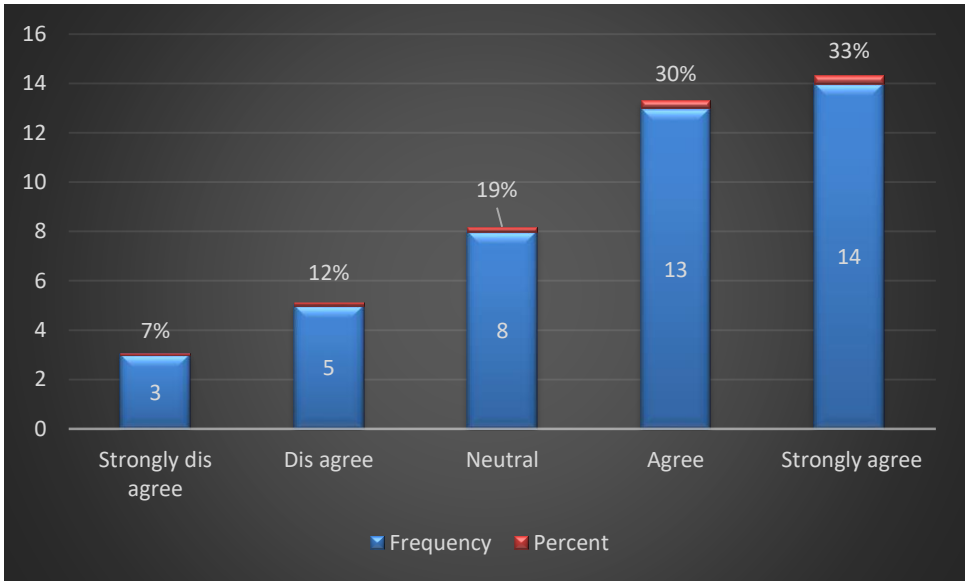

Figure 4.7 The implementation of MMC reduces the environmental impact of construction projects

Source, own survey (2023)

On the opposite side, 7% of the respondents through strongly dis agree and 12% of the respondents through dis agree expresses their dis agreement to the issue. They believe that even if MMC has advantages on the reduction of environmental impacts of construction products, its drawbacks are more significant than its advantages. The effect is already existed in the production site of the construction project precast materials. 19% of the respondents are neutral to this idea. This shows the respondents are declined to give a comment on this idea.

As it is known, most construction projects made of traditional construction method in the long run needs maintenance. This maintenance work in terms of cost is as comparable as the initial investment cost of the construction project. However, if precast materials of MMC are used to produce a construction product, no need of maintenance of the project as compared to the traditional construction method. As shown in Figure 4.8, 49% of the respondents strongly agree and 28% of the respondents agree to the survey questionnaire 'MMC projects are more cost-effective in the long run due to reduced maintenance and operational costs' assessed. This shows most of the respondents accepts the MMC and its effectiveness on the reduction of long-run cost of construction products for its low maintenance and operational costs.

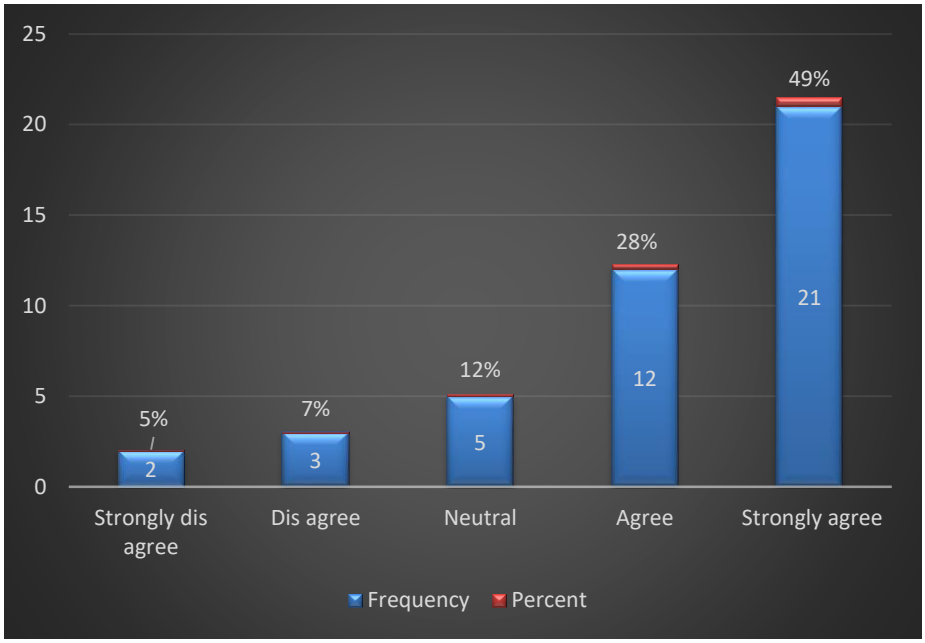

Figure 4.8 MMC projects are more cost-effective in the long run due to reduced maintenance and operational costs

Source, own survey (2023)

In reverse, only 5% of the respondents strongly dis agree and 7% of the respondents dis agree to the idea. This indicates that, they believe that traditional method of construction even it has

cost over long-run due to operational and maintenance costs, the initial cost of MMC is very difficult and it is not applicable in the study area. 12% of the respondents have ben declined to give a comment on this idea. This is because to give a judgement on the two methods of constructions (MMC and traditional method of construction) an assessment should be made.

If MMC is believed that it is more cost-effective as compared to traditional method of construction, adequate training should be to workers for the effective construction of construction projects using modern method. As shown in Figure 4.9, survey data of respondents for the questionnaire 'Adequate training and upskilling opportunities are available for workers to adapt to MMC practices' is presented. Accordingly, 40% of the respondents strongly dis agree and 35% of the respondents dis agree to the idea. This means in the most of construction projects of the respondents there is not enough training of MMC provided for workers. The reason for inadequate training of MMC may be due to different factors. It may be due to unavailability of skilled personnel to give a training or unwillingness of managers of the construction projects to transfer their knowledge to other workers of the construction projects. 14% of the respondents have been declined to give their comments on the issue by choosing neutral.

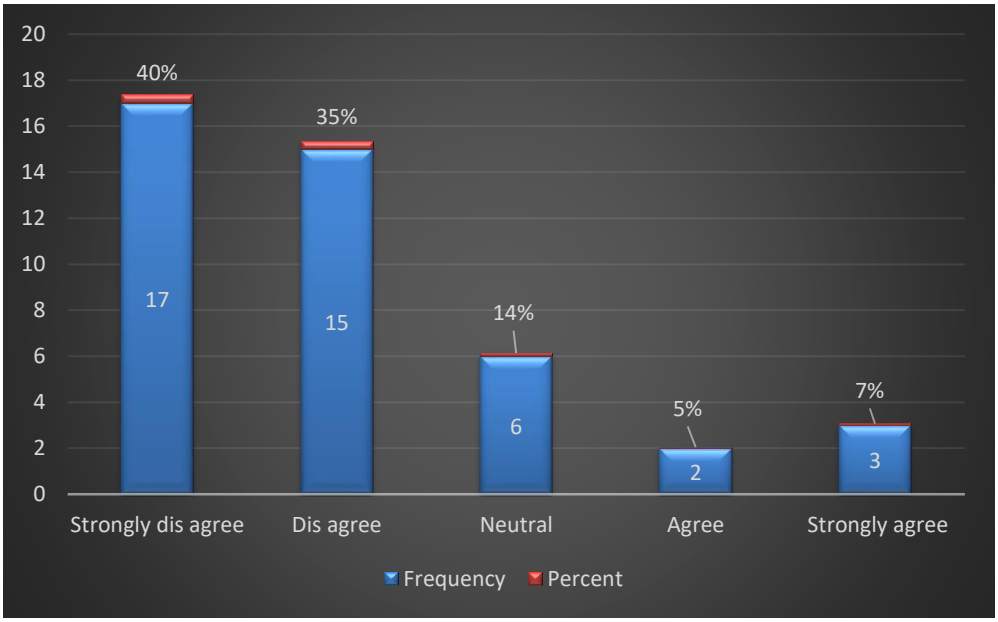

Figure 4.9 Adequate training and upskilling opportunities are available for workers to adapt to MMC practices

Source, own survey (2023)

The response of the remaining 5% of the respondents is agree and 7% of the respondents is strongly agree. This dictates that even if more of the construction projects do not provide adequate training of MMC to their workers, there are some construction managers who are responsible (willing) to provide scheduled trainings to their workers for better and effective construction of construction products by using modern methods. These construction managers believe that skilled workers are an effective asset of their construction project. Due to this they provide scheduled MMC training to their workers.

Construction projects are long term investments as a whole. The project cost of construction projects is in hundreds of millions or in billions. To build a construction project, client should have enough budget and planned design on his construction investment project. Analysis should be made on the long-term investment of the project. To assess this a survey was made on the respondents of the study area and presented as shown in Figure 4.10. Accordingly, 37% of the respondents strongly agree and 28% of the respondents agree for the survey questionnaire 'MMC requires a higher initial investment but provides better return on investment over time' in construction projects. This indicates most of the organizations of the respondents believes that MMC cost effective through long term.

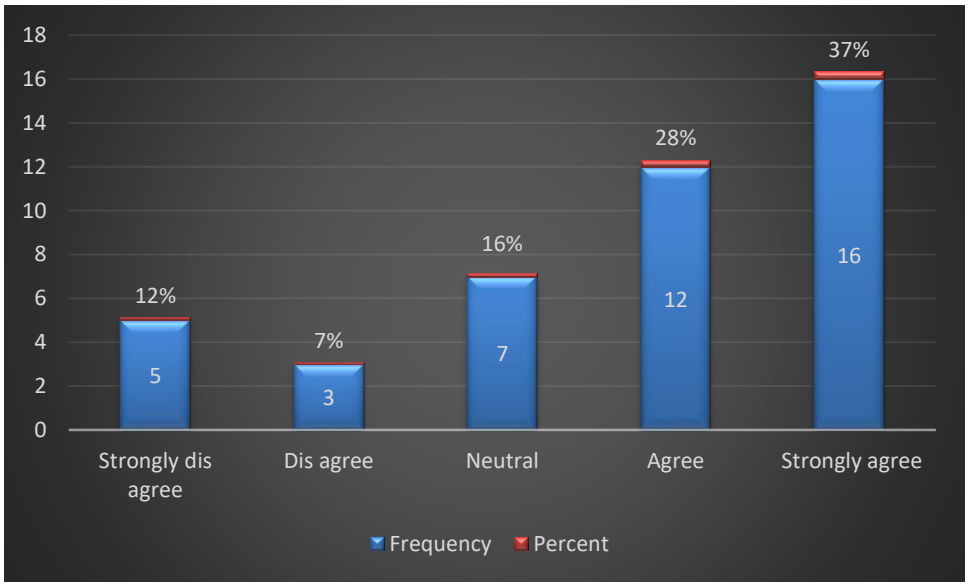

Figure 4.10 MMC requires a higher initial investment but provides better return on investment over time

Source, own survey (2023)

16% of the respondents neither agree nor dis agree on the idea. They have been declined to give a comment by being neutral. They are not in any side of the two (agreement and dis

agreement). Contrarily, 12% of the respondents strongly is agree and 7% of the respondents dis agree on the same issue. This is because, due to the low economical level of our area (Ethiopia as whole), MMC have higher investment costs overall. Especially their initial investment cost is very large and difficult to afford it. Due to this many client of construction projects does not prefer MMC over traditional method of construction. However, this thinking is minor as compared to the construction projects which prefer MMC to traditional method of construction.

As an Ethiopia, most of the codes used throughout the country are a direct copy of other countries. However, without a nationally approved code, building project cannot be constructed. According to the survey analysis made on study area, 42% of the respondents strongly dis agree and 28% of the respondents dis agree in response of the questionnaire 'Regulatory frameworks and building codes are well-adapted to accommodate MMC projects' asked in the study area. This shows that the unavailability of regulatory frameworks and national codes for the utilization of MMC. This is one of the major reasons of non-adapting MMC as an alternative of traditional method of construction.19% of the respondents are declaimed from giving a comment on the issue. This means either they have not no awareness on the issue of MMC or they are not interested in MMC.

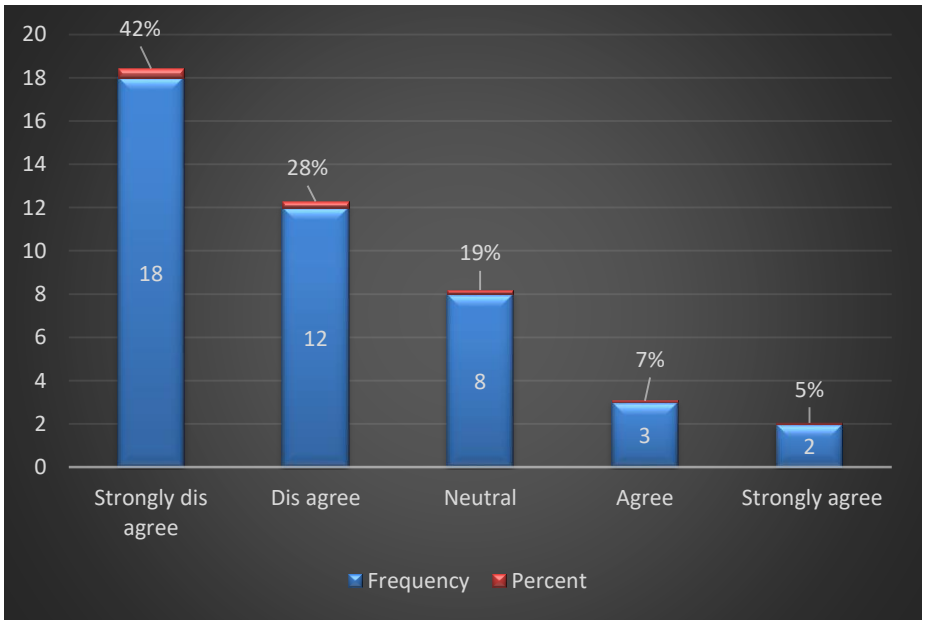

Figure 4.11 Regulatory frameworks and building codes are well-adapted to accommodate MMC projects

Source, own survey (2023)

On the other hand, 7% of the respondents agree and the remaining 5% of the respondents strongly agree to the same issue. This may cause confusion on the availability of codes and regulatory frameworks of the nation (Ethiopia). However, this can be easy if through understanding is made. Some organizations may have developed framework and regulatory framework approved by responsible regulatory as adapted from other countries. As of the other standards of codes used as a copy of other countries codes, MMC codes have been used by some construction projects as indicated in Figure 4.12.

In market comparison is adapted. One method is being compared to other method in order to use the more or not efficient and effective method. The effectiveness and efficiency of a method should be measured with different techniques. To assess the addressing capacity of skilled labor in the market a survey question of 'MMC can address skilled labor shortages in the construction industry' was distributed to respondents and the result is presented in Figure 4.12. accordingly, 33% of the respondents strongly agree and 23% of the respondents agree on it. This means MMC requires minimum number of skilled labors as compared to traditional method of construction in the area of production. Traditional method of construction needs more skilled workers like site engineer, project manager, Forman, mason, quantity surveyor, risk manager, safety manager. However, in the case of MMC only two or three skilled workers can operate and control the construction work.

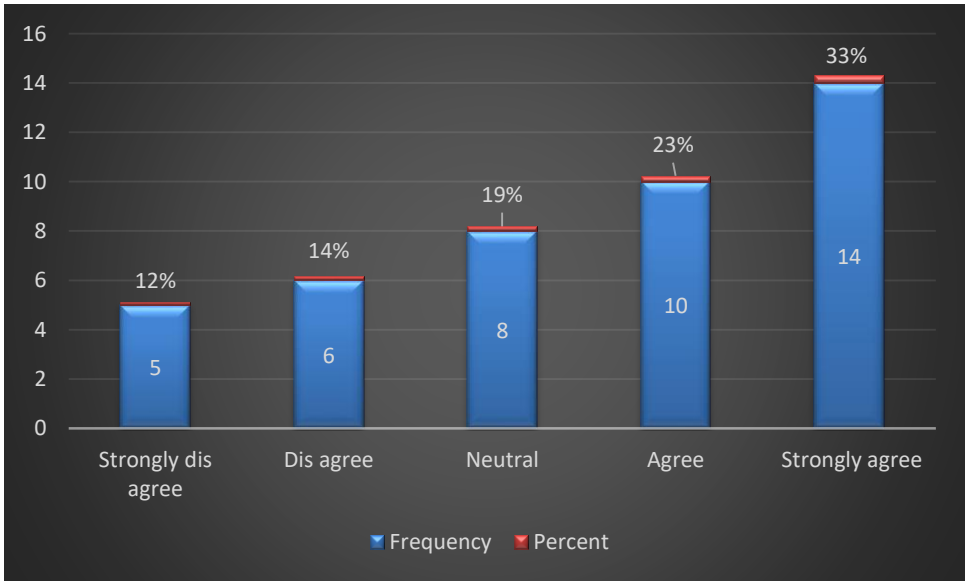

Figure 4.12 MMC can address skilled labor shortages in the construction industry

Source, own survey (2023)

In opposite of this, 12% of the respondents strongly dis agree and 14% of the respondents dis agree to the same issue. As of the opinion of these respondents MMC requires more skilled labor as compared to traditional method of construction. MMC needs more trained and skilled professionals to undertake the construction product. In traditional construction method, workers of the construction project can help each other. This means one worker can cover the responsibility of the other. However, in MMC because the method is new one skilled worker can not work or can not help the responsibility of the other worker. This is the opinion of the respondents in the dis agreement side.

If MMC is believed to be supportive for the sustainable method of construction project, it should get financial support. An assessment was made on this area from respondents by asking 'Financial institutions and lenders are supportive of funding MMC projects' in the study area of the construction projects. As shown in Figure 4.13, 51% of the respondents strongly agree and 30% of the respondents agree. This shows that financial institutions and other borrowing companies are supporting the new MMC method. However, question may be raised here. This is, are the financial institutions and other borrowing companies rely supporting the new MMC method or they are borrowing to get their return over the method? This may be a question for many readers. But it can be understood that if the financial institutions and other borrowing companies do not believe the method, they can not borrow. But this can not be 100% correct answer. Therefore, another study is needed here to identify the right way.5% of the respondents have been declined their comment by being neutral on the idea.

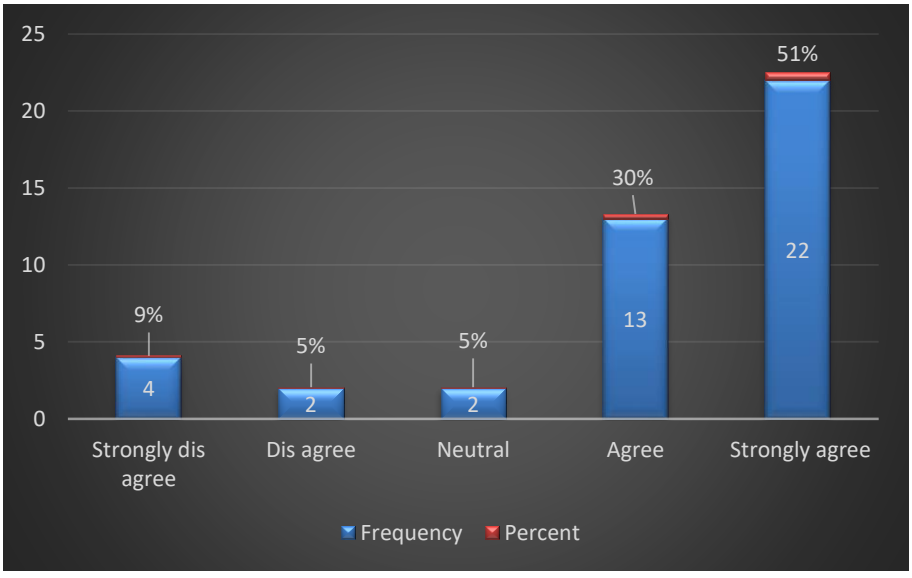

Figure 4.13 Financial institutions and lenders are supportive of funding MMC projects

Source, own survey (2023)

On the other extreme side, 9% of the respondents strongly dis agree and 5% of the respondents dis agree. According to the opinion of these respondents the financial institutions and other borrowing companies are financing to the organization of the MMC not the method of construction. The financing issue is independent of the method of construction. Because the financing institutions and other borrowing companies are financing not only to the organizations that adapt MMC but also for the construction industries which uses traditional method of construction.

To assess the advantages of techniques of MMC over traditional method of construction a survey was made on the study area as presented in Figure 4.14. accordingly, 58% of the respondents strongly agree and 12% of the respondents agree on the survey questionnaire 'MMC techniques allow for greater design flexibility and architectural innovation' distributed for the respondents in the study area. This is in terms of flexibility of design and design innovation. Because, the construction is through templet, once any design you required can be innovated and pre-casted easily. However, in traditional method of construction, the adaptability of new design and technique is challenging through different dimensions. 14% of the respondents restrained from commenting on this idea. They prefer neutral over agreement or dis agreement.

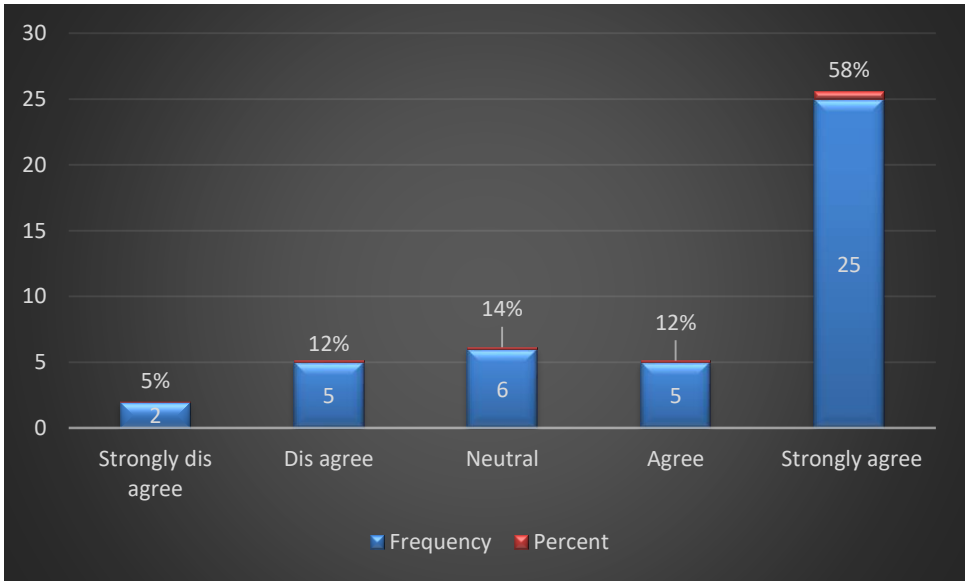

Figure 4.14 MMC techniques allow for greater design flexibility and architectural innovation

Source, own survey (2023)

5% of the respondents and 12% of the respondents strongly dis agree and dis agree respectively over the same idea. This is because they believe that MMC as it is new, even it adapts flexibility in design and architectural innovation its applicability is difficult in this the area of study. For adapting new and innovative ideas, it consumes higher initial investment which is beyond the capacity of the client.

Table 4.3 Impacts of MMC continued

11	The local community and stakeholders are generally receptive to MMC projects	19%	21%	12%	23%	26%	43
12	MMC poses challenges in terms of integrating new technologies and traditional construction practices	7%	9%	12%	35%	37%	43
13	Collaboration and communication among project stakeholders are enhanced in MMC projects	15%	18%	24%	33%	9%	33
14	MMC is a suitable approach for a wide range of construction project types (e.g., residential, commercial, infrastructure)	5%	5%	9%	30%	51%	43
15	MMC reduces the overall risks associated with construction projects	9%	14%	19%	28%	30%	43
16	MMC projects have shorter planning and approval phases compared to traditional projects	5%	7%	12%	30%	47%	43
17	The durability and longevity of MMC-built structures are comparable to or better than traditional structures	9%	7%	5%	37%	42%	43
18	MMC requires a shift in project management strategies and procurement approaches	9%	7%	12%	37%	35%	43

19	MMC adoption is hindered by a lack of awareness and understanding within the industry	7%	19%	28%	26%	21%	43
20	MMC has the potential to revolutionize the construction industry and become the standard approach	7%	12%	14%	33%	35%	43

Source, own survey (2023)

According to the analysis made as shown in Table 4.4 above, the mean of the variables ranges from 3.1 to 4.1. The maximum and minimum values are 1 and 5 respectively. The standard deviation of the values as shown in Table 4.4 varies from 1.1 to 1.6.

Based on the study made by (Payne & Serin, 2023), Nonetheless, contemporary modern methods of construction that typify industry practice in the early 21st century do bring about numerous benefits for the development industry, one of which is better building quality. Evidence from Zhang et al's (2018) review of the literature on prefabricated housing in Hong Kong - applicable to other housing systems - suggests the following development benefits: 1) better building quality and high-quality control 2) improvement of the speed of construction and improved quality control 3) reduction of the overall cost of construction 4) reduction of the construction waste 5) reduction of the environmental impacts 6) improvement of working condition and health and safety of the worker 7) decreased labour 8) lower maintenance and repairs 9) reduction of the environmental impacts to residents around construction sites; and 10) decrease in disputes during construction.

As shown in Table 4.4, the minimum of the descriptive statistics is 1 and the maximum of the descriptive statistics is 5. This comes from the likert scale that ranges between 1 and 5. The mean of the descriptive statistics for every parameter are different. As indicated in the Table 4.4, the mean value is ranging between 3.1 and 4.1. This indicates good mean score value. This analysis aligns with previous work done by (Tara Flynn, 2022). The average mean from the likert scale of assumed equal distribution is 2.5. While in this study the descriptive mean of the results is ranging between 3.1 and 4.1 which is greater than 2.5. this indicates the studying variables are measurable and applicable.

Table 4.4 Descriptive analysis

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
Knowledge1	43	1.00	5.00	3.7907	1.26412
Knowledge2	43	1.00	5.00	4.0233	1.22452
Knowledge3	43	1.00	5.00	3.8837	1.29485
Efficiency1	43	1.00	5.00	4.1628	1.13243
Efficiency2	43	1.00	5.00	4.1860	1.13925
Efficiency3	43	1.00	5.00	3.8837	1.31311
Efficiency4	43	1.00	5.00	3.4651	1.40321
Efficiency5	43	1.00	5.00	3.5116	1.36926
Efficiency6	43	1.00	5.00	3.9535	1.32653
Efficiency7	43	1.00	5.00	3.7209	1.25974
Efficiency8	43	1.00	5.00	4.1395	1.22633
Efficiency9	43	1.00	5.00	4.1395	1.14604
Efficiency10	43	1.00	5.00	3.9535	1.21407
MMC1	43	1.00	5.00	3.7674	1.34230
MMC2	43	1.00	5.00	3.3256	1.64347
MMC3	43	1.00	5.00	3.7907	1.69815
MMC4	43	1.00	5.00	3.5814	1.29528
MMC5	43	1.00	5.00	3.7674	1.19198
MMC6	43	1.00	5.00	3.6279	1.32778
MMC7	43	1.00	5.00	3.1860	1.46801
MMC8	43	1.00	5.00	3.6977	1.45627
MMC9	43	1.00	5.00	3.7674	1.34230
MMC10	43	1.00	5.00	3.3256	1.64347
MMC11	43	1.00	5.00	3.7907	1.69815
MMC12	43	1.00	5.00	3.5814	1.29528
MMC13	43	1.00	5.00	3.7674	1.19198
MMC14	43	1.00	5.00	3.6279	1.32778
MMC15	43	1.00	5.00	3.1860	1.46801
MMC16	43	1.00	5.00	3.6977	1.45627
MMC17	43	1.00	5.00	3.7674	1.34230
MMC18	43	1.00	5.00	3.3256	1.64347
MMC19	43	1.00	5.00	3.7907	1.69815
MMC20	43	1.00	5.00	3.5814	1.29528
Valid N (list wise)	43				

4.5. Improved strategy for application of MMC

For improved strategy for the implementation of modern method of construction companies should develop enough concept about modern method of construction through its employees. The government should also develop a regulatory frameworks and codes to encourage Modern method of construction throughout the country. Designers of construction projects should give enough emphasis for the implementation of modern method of construction as alternative construction method as compared to the conventional construction method. Modern method of construction should be supported with software's like Building Modelling Information (BIM) and technologies for better implementation.

4.6. Summary of Findings

In this study of Modern Methods of Construction on selected construction projects in Addis Ababa, by contractors who participate in the construction building projects, the major findings are listed as follows:

- ✓ **Background Information**: 79% of the respondents were male and the remaining 21% of the respondents were females. The majority of the respondents were in the age range of 26 to 45 years. In which 355 of the respondents were in between 26 and 35 years old and 30% of the respondents were between the age of 36 and 45 years old. 30% of the respondents were site engineers, 16% of the respondents were government officials and 12% of the respondents were project managers. Above 88% of the respondents had greater than five years of experience in the area of construction.
- ✓ **Knowledge of the respondents on the area of MMC**: most of the respondents (above 63% of the respondents) are not familiar with the concept of Modern Method of Construction. Above 77% of the respondents have not adequate knowledge about the benefits of using Modern Method of Construction. The majority of the respondents (above 72% of the respondents) did not understand the construction process involved in Modern Method of Construction.
- ✓ **Efficiency of Modern Method of Construction**: majority of the respondents believe that modern method of construction is efficient method as compared to the conventional method of construction. This efficiency reduces cost, time. Increases flexibility of design, quality of construction products. Minimizes long term investment cost by lowering maintenance and operational costs. MMC improves construction safety,

promotes sustainable and eco-friendly construction practices. However, training and education given to workers in Addis Ababa is not enough.

- ✓ **Impact of modern method of construction(MMC): MMC** improves project efficiency and faster completion times, highest quality construction outcomes compared to traditional methods, reduces the environmental impact of construction projects, cost-effective in the long run due to reduced maintenance and operational costs, requires a higher initial investment but provides better return on investment over time, can address skilled labor shortages in the construction industry, institutions and lenders are supportive of funding MMC projects, allow for greater design flexibility and architectural innovation, suitable approach for a wide range of construction project types, reduces the overall risks associated with construction projects, have shorter planning and approval phases compared to traditional projects, durability and longevity of MMC-built structures are comparable to or better than traditional structures, requires a shift in project management strategies and procurement approaches, its adoption is hindered by a lack of awareness and understanding within the industry, has the potential to revolutionize the construction industry and become the standard approach.

CHAPTER FIVE

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

Based on the findings of the study, the following recommendations have been concluded. These are:

- ✓ The workers of the construction projects in Addis Ababa are not familiar with the concept of modern method of construction, had not adequate knowledge about the benefits of using Modern Method of Construction, and are not understanding the construction process involved in Modern Method of Construction.
- ✓ Modern method of construction is efficient as compared to conventional method of construction in terms of cost, time, quality of product, energy efficiency, architectural flexibility and design options, and sustainable and eco-friendly construction practices. The efficiency of the modern method of construction is applicable if it is handled by efficient, effective and well-trained workers. However, in Addis Ababa enough training and education is not giving to the workers.
- ✓ Modern method of construction is an effective technique to reduce cost and time overrun and to increase quality and customer satisfaction for construction companies. The study found out the application of MMC in Addis Ababa is not satisfactory level. The effectiveness of MMC implementation for the performance of construction projects on the critical factors of a project is overall important for residential building contractors in Addis Ababa
- ✓ The effects of modern method of construction are significant in the area of construction. Improved project efficiency, higher quality construction outcomes compared to traditional methods, reduced the environmental impact, cost-effective in the long run due to reduced maintenance and operational costs, higher initial investment, design flexibility and architectural innovation are among the impacts of Modern method of construction.

5.2. Recommendations

According to the findings and conclusions of this study two type of recommendations have been drown. These are recommendation for the study area and recommendation for future study.

5.2.1. Recommendation for the construction projects

- ✓ The construction projects should train and educate their workers for the effective implementation of modern method of construction
- ✓ The construction companies should get enough concept on the modern method of construction from developed countries which practice MMC
- ✓ The government should develop a regulatory frameworks and codes to encourage Modern method of construction throughout the country.
- ✓ Designers of construction projects should give enough emphasis for the implementation of modern method of construction as alternative construction method as compared to the conventional construction method
- ✓ Modern method of construction should be supported with software's like Building Modelling Information (BIM) and technologies for better implementation

5.2.2. Recommendation for future study

- ✓ Investigation of critical success factors of modern method of construction to develop best techniques of implementation of MMC
- ✓ Critical analysis of efficiency of modern method of construction to identify the improvements over traditional (conventional) method of construction
- ✓ Adaptability of Building Information Modelling (BIM) for modern method of construction

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APPENDIX

Appendix –A: Questionnaire

Survey Questionnaire

Dear Sir,

My name is Leta Fufa, a Master's degree research student of Addis College. I am conducting this study for the purpose of the partial fulfilment of the requirement for the MSc degree in "Construction Technology and Management" with a research title of "**MODERN METHOD OF CONSTRUCTION IN ETHIOPIAN CONSTRUCTION PROJECTS, THE CASE OF SELECTED PUBLIC BUILDINGS IN ADDIS ABABA**". The objective of the study is to analysis the efficient MMC types and method of its practice in construction projects, to analysis the impact of MMC on construction projects, and to develop strategy for application of MMC method in construction projects in Addis Ababa. The questionnaire is for the purpose of academic research in which the confidentiality of all respondents shall be respected.

Thank you!

Leta Fufa (0953865454)

Instructions

The questionnaire will have four parts

Part one will be discussing on the respondent general information and overall project information which the respondent is working on.

Part One: General Information:

Please provide the following demographic information to help us better understand the context of your responses and add (√) in the box below which is appropriate: for you:

1. **Gender**
   - ☐ Male
   - ☐ Female
2. **Age:**
   - ☐ 18-25

☐ 26-35

☐ 36-45

☐ 46 and above

3. **Occupation**

☐ Site Engineer

☐ Government Official

☐ Forman

☐ Project manager

☐ Resident engineer

If other, please specify……

4. **Years of experience in the construction industry**

☐ less than 5 years

☐ 5-10 years

☐ 10-15 years

☐ greater than 15 years

Part Two: Knowledge and Familiarity with Modern Method of Construction

No.	Knowledge on MMC	1	2	3	4	5
1	I am familiar with the concept of Modern Method of Construction					
2	I have adequate knowledge about the benefits of using Modern Method of Construction					
3	I understand the construction process involved in Modern Method of Construction					

Part Three: Efficiency of Modern Method of Construction

A. Methods of MMC

No.	Precast Flat Panel System	1	2	3	4	5
1	Reduces construction time compared to traditional construction methods					
2	Enhances the overall quality of construction projects					
3	Reduces construction costs					
4	Improves construction site safety					
5	Results in better energy efficiency in buildings					
6	Better architectural flexibility and design options					
7	The availability of training and education for workers is adequate in Addis Ababa					
8	Improves construction efficiency and reduces project timelines					
9	Enhances the overall quality and durability of buildings					
10	Promotes sustainable and eco-friendly construction practices					

Please indicate your level of agreement with the following statements regarding the use of modern methods of construction in Addis Ababa. 1=strongly dis agree, 2=dis agree, 3=neutral, 4=agree and 5= strongly agree

No.	Modern Methods of Construction (MMC)	1	2	3	4	5
1	Modern methods of construction (MMC) offer improved project efficiency and faster completion times					
2	MMC techniques lead to higher quality construction outcomes compared to traditional methods					
3	The implementation of MMC reduces the environmental impact of construction projects					
4	MMC projects are more cost-effective in the long run due to reduced maintenance and operational costs					
5	Adequate training and upskilling opportunities are available for workers to adapt to MMC practices					

6	MMC requires a higher initial investment but provides better return on investment over time					
7	Regulatory frameworks and building codes are well-adapted to accommodate MMC projects					
8	MMC can address skilled labor shortages in the construction industry					
9	Financial institutions and lenders are supportive of funding MMC projects					
10	MMC techniques allow for greater design flexibility and architectural innovation					
11	The local community and stakeholders are generally receptive to MMC projects					
12	MMC poses challenges in terms of integrating new technologies and traditional construction practices					
13	Collaboration and communication among project stakeholders are enhanced in MMC projects					
14	MMC is a suitable approach for a wide range of construction project types (e.g., residential, commercial, infrastructure)					
15	MMC reduces the overall risks associated with construction projects					
16	MMC projects have shorter planning and approval phases compared to traditional projects					
17	The durability and longevity of MMC-built structures are comparable to or better than traditional structures					
18	MMC requires a shift in project management strategies and procurement approaches					

19	MMC adoption is hindered by a lack of awareness and understanding within the industry					
20	MMC has the potential to revolutionize the construction industry and become the standard approach					

Part Four: Open ended question (For additional information)

Please provide any additional comments or suggestions related to Modern Method of Construction in Addis Ababa

_____

_____

_____

_____.

Appendix-B: Analysis Data

Background Information of Respondents		
Gender	Frequency	Percent
Male	34	79%
Female	9	21%
Total	43	100%
Age	Frequency	Percent
18-25	8	19%
26-35	15	35%
36-45	13	30%
46 and above	7	16%
Total	43	100%
Occupation	Frequency	Percent
Site Engineer	13	30%
Government Official	7	16%
Forman	8	19%
Project manager	5	12%
Resident engineer	10	23%
Total	43	100%
Experience	Frequency	Percent
less than 5 years	5	12%
5-10 years	10	23%
10-15 years	13	30%
greater than 15 years	15	35%
Total	43	100%

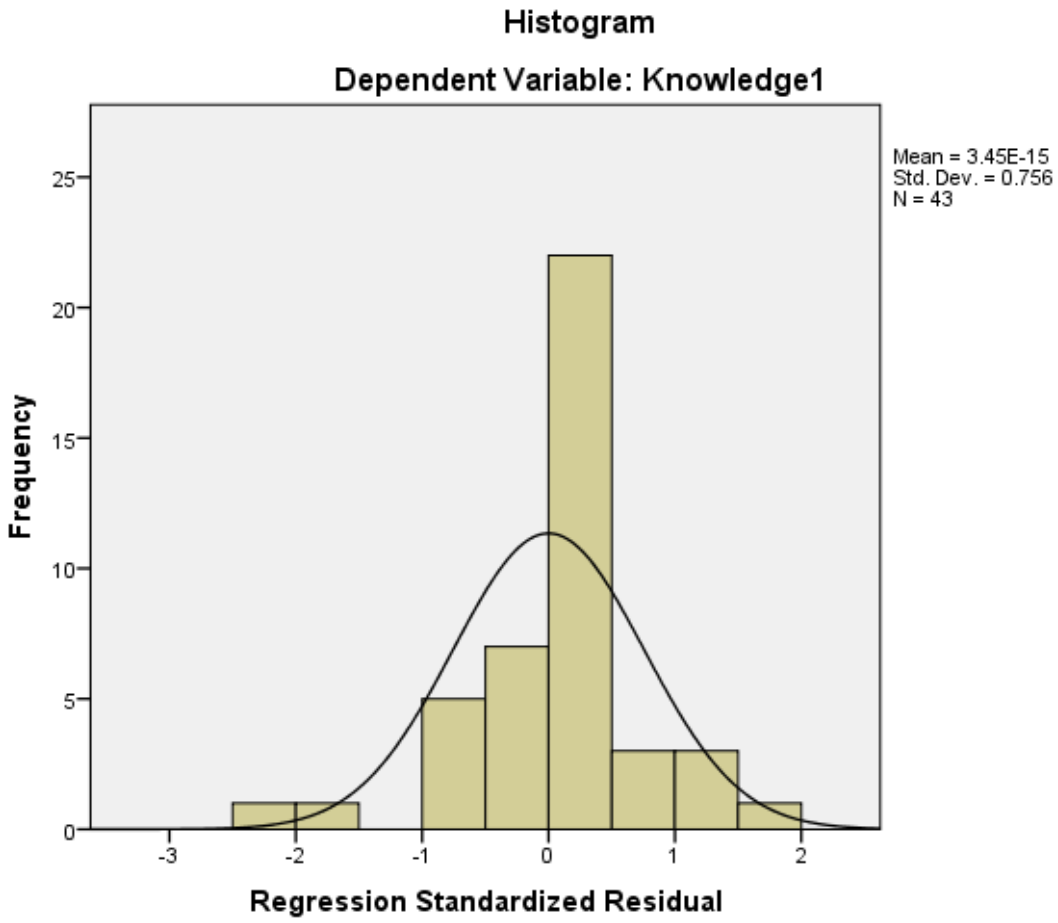
Where, 1=strongly dis agree, 2= dis agree, 3=neutral, 4= agree and 5= strongly agree

No.	Specific Objective-1	1	2	3	4	5	Total
1	I am familiar with the concept of Modern Method of Construction	3	4	9	10	17	43
2	I have adequate knowledge about the benefits of using Modern Method of Construction	3	3	4	13	20	43

3	I understand the construction process involved in Modern Method of Construction	4	3	5	13	18	43
4	Reduces construction time compared to traditional construction methods	2	3	3	13	22	43
5	Enhances the overall quality of construction projects	2	3	3	12	23	43
6	Reduces construction costs	3	5	6	9	20	43
7	Improves construction site safety	6	5	8	11	13	43
8	Results in better energy efficiency in buildings	5	6	7	12	13	43
9	Better architectural flexibility and design options	2	5	5	6	25	43
10	The availability of training and education for workers is adequate in Addis Ababa	4	3	8	14	14	43
11	Improves construction efficiency and reduces project timelines	3	2	5	9	24	43
12	Enhances the overall quality and durability of buildings	2	3	4	12	23	44
13	Promotes sustainable and eco-friendly construction practices	3	2	9	11	18	43

No.	Specific objective-2	1	2	3	4	5	Total
1	Reduces construction time compared to traditional construction methods	2	3	3	13	22	43
2	Enhances the overall quality of construction projects	2	3	3	12	23	43
3	Reduces construction costs	3	5	6	9	20	43
4	Improves construction site safety	6	5	8	11	13	43
5	Results in better energy efficiency in buildings	5	6	7	12	13	43
6	Better architectural flexibility and design options	2	5	5	6	25	43
7	The availability of training and education for workers is adequate in Addis Ababa	4	3	8	14	14	43
8	Improves construction efficiency and reduces project timelines	3	2	5	9	24	43

9	Enhances the overall quality and durability of buildings	2	3	4	11	23	43
10	Promotes sustainable and eco-friendly construction practices	3	2	9	11	18	43
11	The local community and stakeholders are generally receptive to MMC projects	8	9	5	10	11	43
12	MMC poses challenges in terms of integrating new technologies and traditional construction practices	3	4	5	15	16	43
13	Collaboration and communication among project stakeholders are enhanced in MMC projects	5	6	8	11	3	33
14	MMC is a suitable approach for a wide range of construction project types (e.g., residential, commercial, infrastructure)	2	2	4	13	22	43
15	MMC reduces the overall risks associated with construction projects	4	6	8	12	13	43
16	MMC projects have shorter planning and approval phases compared to traditional projects	2	3	5	13	20	43
17	The durability and longevity of MMC-built structures are comparable to or better than traditional structures	4	3	2	16	18	43
18	MMC requires a shift in project management strategies and procurement approaches	4	3	5	16	15	43
19	MMC adoption is hindered by a lack of awareness and understanding within the industry	3	8	12	11	9	43
20	MMC has the potential to revolutionize the construction industry and become the standard approach	3	5	6	14	15	43



Model Summary[b]				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.988[a]	.976	.957	.26090
a. Predictors: (Constant), MMC20, MMC19, Efficiency6, MMC15, MMC18, Efficiency1, Efficiency8, MMC16, Efficiency7, Efficiency3, Efficiency5, MMC17, Efficiency10, MMC14, Efficiency4, MMC13, Efficiency9, Efficiency2				
b. Dependent Variable: Knowledge1				

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	65.483	18	3.638	53.446	.000[b]
	Residual	1.634	24	.068		
	Total	67.116	42			
a. Dependent Variable: Knowledge1						
b. Predictors: (Constant), MMC20, MMC19, Efficiency6, MMC15, MMC18, Efficiency1, Efficiency8, MMC16, Efficiency7, Efficiency3, Efficiency5, MMC17, Efficiency10, MMC14, Efficiency4, MMC13, Efficiency9, Efficiency2						

Model Summary[b]									
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.982[a]	.964	.952	.27660	.964	84.525	10	32	.000
a. Predictors: (Constant), Efficiency10, Efficiency6, Efficiency4, Efficiency1, Efficiency7, Efficiency8, Efficiency3, Efficiency5, Efficiency9, Efficiency2									
b. Dependent Variable: Knowledge1									

Correlations												
		Knowledge2	Efficiency1	Efficiency2	Efficiency3	Efficiency4	Efficiency5	Efficiency6	Efficiency7	Efficiency8	Efficiency9	Efficiency10
Pearson Correlation	Knowledge2	1.000	.959	.953	.964	.922	.916	.895	.930	.965	.965	.962
	Efficiency1	.959	1.000	.991	.942	.895	.897	.909	.917	.961	.991	.941
	Efficiency2	.953	.991	1.000	.938	.898	.899	.920	.916	.969	.983	.936
	Efficiency3	.964	.942	.938	1.000	.935	.934	.926	.944	.942	.945	.967
	Efficiency4	.922	.895	.898	.935	1.000	.988	.920	.951	.916	.906	.921
	Efficiency5	.916	.897	.899	.934	.988	1.000	.931	.954	.921	.909	.931
	Efficiency6	.895	.909	.920	.926	.920	.931	1.000	.904	.926	.913	.900
	Efficiency7	.930	.917	.916	.944	.951	.954	.904	1.000	.920	.918	.941
	Efficiency8	.965	.961	.969	.942	.916	.921	.926	.920	1.000	.968	.948
	Efficiency9	.965	.991	.983	.945	.906	.909	.913	.918	.968	1.000	.946
	Efficiency10	.962	.941	.936	.967	.921	.931	.900	.941	.948	.946	1.000
Sig. (1-tailed)	Knowledge2	.	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	Efficiency1	.000	.	.000	.000	.000	.000	.000	.000	.000	.000	.000
	Efficiency2	.000	.000	.	.000	.000	.000	.000	.000	.000	.000	.000

	Efficiency3	.000	.000	.000	.	.000	.000	.000	.000	.000	.000	.000
	Efficiency4	.000	.000	.000	.000	.	.000	.000	.000	.000	.000	.000
	Efficiency5	.000	.000	.000	.000	.000	.	.000	.000	.000	.000	.000
	Efficiency6	.000	.000	.000	.000	.000	.000	.	.000	.000	.000	.000
	Efficiency7	.000	.000	.000	.000	.000	.000	.000	.	.000	.000	.000
	Efficiency8	.000	.000	.000	.000	.000	.000	.000	.000	.	.000	.000
	Efficiency9	.000	.000	.000	.000	.000	.000	.000	.000	.000	.	.000
	Efficiency10	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.
N	Knowledge2	43	43	43	43	43	43	43	43	43	43	43
	Efficiency1	43	43	43	43	43	43	43	43	43	43	43
	Efficiency2	43	43	43	43	43	43	43	43	43	43	43
	Efficiency3	43	43	43	43	43	43	43	43	43	43	43
	Efficiency4	43	43	43	43	43	43	43	43	43	43	43
	Efficiency5	43	43	43	43	43	43	43	43	43	43	43
	Efficiency6	43	43	43	43	43	43	43	43	43	43	43
	Efficiency7	43	43	43	43	43	43	43	43	43	43	43
	Efficiency8	43	43	43	43	43	43	43	43	43	43	43
	Efficiency9	43	43	43	43	43	43	43	43	43	43	43
	Efficiency10	43	43	43	43	43	43	43	43	43	43	43