A Successful Implementation of Mass Modular Construction in Ethiopia: A Case Study of Addis Ababa

Negese Dabi Tola

A Thesis Submitted to the department of Civil Engineering

School of Civil Engineering and Architecture

Presented in Partial Fulfillment of the Requirement for the Degree of Master's in Civil Engineering (Specialized in Construction Engineering and Management),

Office of Graduate Studies

Adama Science and Technology University

June, 2024

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DECLARATION

I hereby declare that this Master Thesis entitled "A Successful Implementation of Mass Modular Construction in Ethiopia: A Case Study of Addis Ababa" is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation

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RECOMMENDATION

I, the advisor of this thesis, hereby certify that I have read the revised version of the thesis entitled "A Successful Implementation of Mass Modular Construction in Ethiopia: A Case Study of Addis Ababa" prepared under my guidance by Negese Dabi Tola submitted in partial fulfillment of the requirements for the degree of Mater's of Science in Civil Engineering. Therefore, I recommend the submission of revised version of the thesis to the department following the applicable procedures.

______________________	________________	_____________
Major Advisor	Signature	Date

APPROVAL PAGE OF THESIS

I, the advisors of the thesis entitled "A Successful Implementation of Mass Modular Construction in Ethiopia: A Case Study of Addis Ababa" and developed by_Negese Dabi Tola hereby certify that the_recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

Major Advisor	Signature	Date

We, the undersigned, members of the Board of Examiners of the thesis by Negese Dabi Tola have read and evaluated the thesis entitled "A Successful Implementation of Mass Modular Construction in Ethiopia: A Case Study of Addis Ababa" and examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in Civil Engineering.

Chairperson	Signature	Date
Internal Examiner	Signature	Date
Eternal Examiner	Signature	Date

Finally, approval and acceptance of the thesis is contingent upon submission of its final copy to the Office of Postgraduate Studies (OPGS) through the Department Graduate Council (DGC) and School Graduate Committee (SGC).

Department Head	Signature	Date
School Dean	Signature	Date
Office of Postgraduate Studies, Dean	Signature	Date

AKNOLGEMENT

I would like to sincerely thank my adviser at ASTU's School of Civil Engineering and Architecture, Department of Civil Engineering, **Fikreyesus Demeke (PhD)** for his insightful counsel, unwavering support, and expert assistance. I also like to express my gratitude to the Civil Engineering Department faculty for their academic and scientific guidance during my time at ASTU.

Lastly, I would want to express my gratitude to everyone who took part in the research process; your participation has made this thesis a success.

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APHMI	Addis prefab houses manufacturing Industries
BIM	Building Information Modeling
CMA	Certified Modular Architect
EHS	Environment, Health, and Safety
GTZ	German Technical Cooperation
IFC	International Finance Corporation
ISO	International standard Organization
NSIP	National Sustainable Infrastructure Protocol
PLC	Private Limited Company
PPVC	Prefabricated Prefinished Volumetric Construction
SDGs	Sustainable Development Goals
SECU	Sustainable emerging city unit
TBL	Triple Bottom Line
TOPSIS	Techniques for order preference by similarity to ideal solution

ABSTRACT

The rapid urbanization and population growth in developing countries, such as Ethiopia, have created a press need for affordable and sustainable housing solutions. Traditional construction methods have struggled to keep up with the increasing demand efficiently and cost-effectively. This situation has prompted a closer look at mass modular construction as a viable alternative for countries like Ethiopia. This study delves into the drivers, challenges, and enabling strategies that influence the successful implementation of mass modular construction, particularly in Addis Ababa. To gain insights, a systematic review of existing literature was conducted to pinpoint the key factors influencing the implementation of mass modular construction. Employing a fuzzy-based questionnaire within a descriptive research framework allowed for a comprehensive consideration of uncertainties in respondents' perspectives. The research methodology further involved the use of a stratified random sampling technique to gather data from a diverse pool of participants, which was subsequently meticulously analyzed using a fuzzy technique for order preference by similarity to ideal situation approach to unearth the drivers, hurdles, and enablers crucial for the successful execution of mass modular construction. The study outcomes revealed critical drivers for embracing mass modular construction, including aspects such as the optimized land use, standardization protocols, operational efficiencies, effective waste management and good management enhancement. Addressing challenges like regulatory gaps, the lack of technology assessment institutions, insufficiencies in educational programs, shortages of qualified contractors, and inadequacies in workforce skills emerges as pivotal in ensuring a smooth implementation process. The research also identified enabling strategies that encompass activities like awareness campaigns, fostering collaborative resource-sharing, education enhancement initiatives, the adoption of holistic approaches, and the promotion of a conducive environment within the construction sector. By offering a systematic evaluation of paramount factors associated with mass modular construction, prioritizing key areas, and proposing concrete strategies to combat challenges, this research aims to guide and facilitate the successful execution of mass modular construction projects not only in Addis Ababa but also in similar urban landscapes.

Key words: Mass modular, Construction, Drivers, Challenges, Enablers

CHAPTER ONE
INTRODUCTION

1.1.Background of Study

The construction industry is a major sector that contributes significantly to world economic growth and development. However, traditional construction methods have been chastised for their inefficiency, high costs, and bad impact on the environment. Modular construction has recently emerged as a possible alternative to traditional construction methods because of its potential to improve efficiency, reduce costs, and enhance sustainability (Fei et al., 2021).

Rapid urbanization and population growth in developing country such as Ethiopia have resulted in an increased demand for affordable and sustainable housing solution. Traditional construction methods are frequently insufficient to handle this demand efficiently and cost-effectively. Mass modular construction, which involves prefabricating building components in a factory setting and then assembling them on-site, has emerged as a potential solution to this demand. However, its successful implementation in Ethiopia context face various challenges and require enabling strategies (Dube, 2019; Mezgebo, 2021; Moshinsky, 2015).

Mass modular construction is a way of constructing structures with prefabricated modules manufactured off-site and assembled on-site. This method has gained popularity in developed countries due to its ability to reduce building time, cost, and environmental impact. However, in developing countries like Ethiopia, the execution and sustainability of mass modular building encounter several challenges (Generalova et al., 2016; Jensen, 2010).

Ethiopia's economy is quickly growing, with a high demand for cheap housing, infrastructure, and other construction projects. Traditional construction methods in the country are generally inefficient, expensive, and time-consuming. Mass modular construction has the potential to address these difficulties while also helping the country achieve its development goals. However, there is a lack of research and methodology particular to the Ethiopian environment that can guide the successful implementation of mass modular construction (Weldesilassie & Gebrehiwot, 2017; Woldeeyesus, 2017).

The specific objectives of the study was outlined, emphasizing the need to identify and analyze the key drivers, challenges, and enabling strategies that influence the adoption of mass modular construction in Addis Ababa. The absence of existing research and literature on this topic was addressed, underlining the significance of closing this knowledge gap in order to influence future building decision-making and policy development. However, there must be a prospect for the successful development of mass modular construction in developing nations. As a result, the goal of this research is to get a better knowledge of the drivers, challenges, and enabling strategies that influence the effective implementation of mass modular construction in Ethiopia, particularly in Addis Ababa.

1.2.Statement of the Problems

Rapid urbanization and population increase in developing country such as Ethiopia have created a greater demand for affordable and sustainable housing solution. Mass modular construction has emerged as a promising solution to satisfy this demand. However, its successful implementation in the Ethiopian context face various challenges and require enabling strategies (Dube, 2019; Mezgebo, 2021; Moshinsky, 2015). As a result, there is a demand to comprehensively analyze the key drivers, challenges, and enabling strategies for the successful implementation of mass modular construction in Addis Ababa, as well as to forecast the success of mass modular construction that can guide policymakers, developers, and other stakeholders in effectively implementing mass modular construction projects in similar developing country contexts.

Ethiopia's construction industry has various obstacles, including a lack of affordable housing, inefficient construction processes, and limited infrastructural development. In response to these issues, mass modular construction is gaining popularity as a viable solution to the housing scarcity and increased construction efficiency. However, the successful implementation of mass modular construction in Addis Ababa is hindered by a variety of technological, legal, and capacity constraints. As a result, there is a need to examine the key drivers of mass modular construction in Addis Ababa, as well as the obstacles and barriers to its successful execution. Furthermore, building enabling policies for the long-term viability of mass modular construction in Addis Ababa is vital for promoting its sustainable acceptance and integration into the construction sector (Lafhaj et al., 2016).

Despite the potential benefits of mass modular construction in Ethiopia, there are several problems and barriers to its implementation. Technical obstacles, such as a lack of knowledge and adequate technology, may hinder the widespread implementation of modular construction.

Economic problems, such as high initial cost and affordability concerns, provide substantial barriers to the implementation of mass modular construction projects. Furthermore, social and cultural elements such as acceptance and perception may have an impact on the viability and acceptability of mass modular construction in Addis Ababa. As a result, it is necessary to analyze these problems in order to develop ways to solve them and allow the successful implementation of mass modular building in Ethiopia (Abdelmageed et al., 2020a; Abebe, 2020).

While mass modular building has the ability to meet Ethiopia's housing and infrastructure needs, there is a lack of understanding of the enabling strategies and best practices for its implementation. Analyzing successful case studies and best practices from other developing country is critical for identifying the strategies used for effective mass modular construction implementation. Furthermore, it is necessary to investigate the legislative and policy frameworks that can facilitate the acceptance and implementation of mass modular construction in Ethiopia. Furthermore, understanding the role of stakeholders such as the government, private sector, and local communities, as well as their participation in the implementation process, is critical for the effective adoption of mass modular construction in Addis Ababa. There is a need to analyze enabling strategies and best practices for adopting mass modular construction (Abdelmageed et al., 2020a; Cantu, 2020; Ham & Opdenakker, 2023; Musa et al., 2016).

The primary issue addressed by this study is the lack of a comprehensive strategies that incorporates the key drivers, challenges, and enabling strategies for the successful implementation of mass modular construction in Ethiopia, with an emphasis on Addis Ababa. This study would give policymakers, practitioners, and other stakeholders with practical information on how to effectively promote and support the implementation of mass modular building in the Addis Ababa construction industry. As a result, the research aims to fill this gap by analyzing the key drivers of mass modular construction, investigating the barriers to its successful implementation, and evaluating enabling strategies and best practices, as well as predicting the likelihood of mass modular construction's success. These objectives were to help fill a research gap by giving a full understanding of the elements driving mass modular construction in the Ethiopian setting, as well as practical recommendations for successful mass modular construction implementation.

1.3.Research Questions

In relation to the research questions, this study seeks to answer the following questions:

- What are the key drivers of mass modular construction in the Ethiopian context and how do they contribute to successful implementation?
- What are the challenges to the successful implementation of mass modular construction in Ethiopia?
- What are the enabling strategies and best practices for implementing mass modular construction in Ethiopia?

1.4.Objective of the Study

1.4.1. General objective of the Study

The general objective of this study is to investigate the drivers, challenges, and enabling strategies that influence the successful mass modular construction in Ethiopia, specifically in Addis Ababa.

1.4.2. Specific objectives of the Study

The specific objectives of this study are:

- To analyzing the key drivers of mass modular construction in the Ethiopian context.
- To investigating the challenges to the successful implementation of mass modular construction in Ethiopia.
- To investigate the enabling strategies and best practices for implementing mass modular construction in Ethiopia.

1.5.Scope of the Study

The scope of the study is limited on mass modular construction in Ethiopia, Addis Ababa. The research focused on the key drivers, challenges to successful implementation, and enabling strategies and best practices for mass modular building. Furthermore, the study explore capacity building, stakeholder involvement, technology transfer, and knowledge exchange as enabling techniques for implementing mass modular construction in Ethiopia. The study could provide valuable insights into the specific factors influencing mass modular construction in Ethiopia, and contribute to the development of comprehensive enabling strategies and best practices for policymakers, developers, and other stakeholders to effectively implement mass modular construction projects in Addis Ababa.

1.6.Significances of the Study

The significance of this study was lies in its ability to solve the great demand for affordable and sustainable housing solution in developing countries, specifically Ethiopia. The study's analysis of the key drivers of mass modular construction in Ethiopia could provide useful insights into the variables driving the adoption of mass modular construction methods, informing policy decisions and investment strategies. Furthermore, by studying the barriers to the successful implementation of mass modular building in Ethiopia, the study was able to propose areas for improvement and interventions. This research resulted in the development of specific strategies to solve these problems, hence aiding the successful implementation of mass modular construction projects across the country.

Finally, by investigating enabling strategies and best practices for implementing mass modular construction in Ethiopia, the study may provide useful guidance to stakeholders involved in such projects. This research will help to guarantee that these initiatives are conducted in a sustainable and successful manner, resulting in long-term benefits for both the housing sector and the overall economy. This study was served as a valuable resource for policymakers, developers, and other stakeholders in similar developing country, providing a roadmap for successful implementing of mass modular construction projects.

1.7.Limitations the Study

This study has limitations, including a limited data availability is a lack of comprehensive and reliable data on mass modular construction in Ethiopia, which could limit the depth and accuracy of the investigation. Access to stakeholders which is gaining access to key stakeholders involved in mass modular construction projects in Ethiopia may be challenging. Some stakeholders may be reluctant to participate or share information due to various reasons, such as confidentiality concerns or competition. Lack of long-term data which is mass modular construction is a relatively new concept in Ethiopia, and there may be limited long-term data available on the success or challenges of implementing this construction method. This could restrict the ability to assess the long-term viability and sustainability of mass modular construction in Ethiopia.

1.8.Organization of the Thesis

This thesis would be organized with the preliminary pages of the thesis document consisted of the cover page, title page, approval sheet, acknowledgment, table of content, list of tables, list of figures, acronyms and abstract. The main body part has five chapters, within each chapter there is different but interrelated subtopics. The first chapter contains the introduction part which comprised the background information, problem statement, research questions, objectives, significance, scope, operational definition, limitation and organization of the study. The second chapter consisted of the literature review part. The third chapter is the research methodology which covers the study area, research design, population and sampling frame, sampling techniques, sample size determination, data collection method, data analysis method, validity & reliability and ethical consideration. The fourth chapter is the results and discussion part of the study which concerned about data presentation and discussions. This documented the analysis of the primary and secondary facts with the mixed research approach. The last chapter provided the conclusion and recommendation of the study.

CHAPTER TWO

LITERATURE REVIEW

2.1.Introduction

This chapter describes the research related literature review that was used in the research study. These include the research theory, concepts and ideology that exist with regard to the theoretical and leading to study gap identification of the successful implementation of mass modular construction.

2.2.Mass Modular Construction:

2.2.1. Definition and concepts of mass modular construction

Modular refers to a method of construction where a building is assembled from prefabricated modules or units that are manufactured in a factory setting and then transported to the construction site for assembly. In an engineering environment, it is intimately related with the notion of prefabrication, which consists in "the practice of assembling components of a building out of the construction site (factory or other) before the final assembly in the construction" (Ferrer, 2019). The term "modular" describes a construction method or process in which individual modules stand alone or are joined together to form bigger structures (Geleta, 2019).

Mass modular construction, often known as modular building, is a construction technology that employs prefabricated building components or modules that are produced off-site and transported to the construction site for assembly. These modules are usually standardized and can be joined or stacked to produce a range of building kinds, such as residential, commercial, and institutional structures (Generalova et al., 2016a).

According to Kolbeck et al. (2023), indicated that the core principles of mass modular construction include prefabrication, which is the process of creating building components in a factory-controlled environment where they can be created with high precision and quality before being delivered to the construction site. Modules are designed to correspond to defined dimensions and requirements, allowing for simple assembly and integration into various building layouts. Assembly is the on-site assembly of prefabricated modules to form a full building structure, which can significantly reduce construction time and labor costs. Flexibility is the capacity to adjust and adapt modular designs to meet unique project requirements while still taking advantage of mass manufacturing advantages. Sustainability is the potential for reduce material waste, energy consumption and environmental effect can be reduced by using controlled manufacturing methods and efficient prefabricated component transportation. Cost and time reductions are the potential savings due to reduce on-site labor requirements, shorter construction timetables, and fewer construction-related disturbances.

As a result, mass modular construction has grown in popularity around the world due to its capacity to address housing shortages, enhance construction efficiency, and achieve sustainability goals. The concept evolves with advances in technology, design, and manufacturing processes, making it a more realistic alternative for addressing construction issues in a variety of developing countries.

2.2.2. History of successful implementation of mass modular construction

There are several notable examples of effective mass modular construction application in both developed and developing countries. These case studies demonstrate how modular building has been used to meet housing shortages, infrastructural requirements, and urbanization difficulties (Generalova et al., 2016a). A few notable examples are as follows:

China has been a pioneer in mass modular construction, notably in meeting rising urbanization and housing needs. The government has implemented large-scale modular construction projects, like as the "Mini Sky City" in Changsha, a 57-story skyscraper built in 19 days with prefabricated modules. This project demonstrated the speed and effectiveness of modular construction to satisfy urban housing needs (Liu et al., 2017).

India has also had effective examples of widespread modular construction. For example, the "Aadhar" project in Mumbai used prefabricated modules to build cheap housing units for low-income households. The project demonstrated how modular construction can deliver excellent housing at a rapid rate, helping to overcome the housing problem in urban areas (Sachdev, 2018).

In South Africa, projects have been launched to address housing difficulties through mass modular construction. The "shack" initiative in Cape Town entailed the construction of energy-efficient, modular dwellings for informal communities. This project highlighted the potential of modular construction in providing sustainable and dignified housing alternatives for neglected areas (Dupwa & Laryea, 2017).

Brazil has likewise embraced mass modular construction to provide affordable housing. The "Minha Casa Minha Vida" (My House, My Life) program uses modular construction techniques to provide low-cost housing units around the country. This effort has proved the scalability of modular construction in meeting the housing demands of low-income groups (Lonardoni et al., 2013).

In Kenya, the "Koto Housing Kenya" project has used mass modular building to provide affordable and sustainable housing. The use of prefabricated modules has allowed for speedy building of homes, adding to attempts to overcome the country's housing crisis (Kieti et al., 2018).

Addis Prefab House Manufacturing Industries S.C. (APHMI): these units are expected to eventually become independent subsidiary corporations. The real estate business unit builds dwellings with the nine prefabricated construction materials that the manufacturing business unit will produce (Geleta, 2019 and ethio-construction.net, 2017). YBEL industrial private limited firm (PLC) is an Ethiopian grade one construction firm and building material manufacturer. Until recently, the industrial PLC was primarily involved in the manufacture of magnesium board factory-made, non-insulating sheathing board products. The company's objective is to provide economical, efficient, and safe housing and building projects by transitioning from traditional construction methods to new ones (Muluken Tessera, 2020). Prototype SECU (sustainable emerging city unit) is an experimental prototype for emerging home structures in Addis Ababa that was implemented in April and May of 2012. SECU is a testing and experimental research project for rapidly growing settlements and rural areas that investigates alternatives to traditional housing models. All building elements consist of prefabricated standard strawboard elements (Donath, 2012). However, not all enterprises may be successful in implementing mass modular construction in Ethiopia to address diverse socioeconomic difficulties.

Thus, these case studies demonstrate how mass modular construction has been successfully applied in developing country to meet a variety of socioeconomic difficulties. They emphasize modular construction's ability to provide economical, quick, and scalable housing and infrastructure solutions. Furthermore, these case studies demonstrate the flexibility of modular building techniques to a variety of settings in developing countries, as well as their positive influence on local people.

2.3.Factors affecting the implementation of mass modular construction

2.3.1. Drivers of Mass Modular Construction

Mass modular construction, often known as prefabricated or modular construction, has gained popularity as an innovative solution to construction industry issues. This literature study addresses the key drivers for the adoption and growth of mass modular construction (Thai et al., 2020).

Cost savings are an economic motivator, as mass production and standardized designs in modular construction lead to reduce material costs, labor expenses, and overall project costs (Solomon, 2023). Increased productivity is an economic driver which Factory-controlled production environments and efficient assembly procedures improve productivity and reduce construction time (Sreekumar, 2018). Affordable housing is a social driver, and mass modular building provides a cost-effective option to address the increasing need for cheap housing, particularly in urban areas (Khan et al., 2022). Rapid urbanization is a social factor that creates a high demand for dwelling units in cities. This need can be efficiently satisfied through modular construction (Efficiency et al., 2016). Sustainability is an environmental driver. Modular building frequently uses sustainable materials, reduces waste, and minimizes environmental effect (Sullcapuma Morales, 2023). Energy efficiency is an environmental driver, and prefabricated modules can be constructed to satisfy high energy efficiency standards, lowering energy consumption and operating costs (Chen, 2020).

Furthermore, developments in materials are a technological driver which Innovations in materials, such as lightweight and high-strength composites, have improved the efficiency and versatility of modular construction (Ralegaonkar et al., 2016). Design optimization is a technology driver in which building information modeling (BIM) and other digital tools enable improved design and coordination of modular elements (Hafeez, 2009). Government assistance is a policy and regulatory driver, which means that government policies, incentives, and regulations can increase the development and implementation of mass modular construction (International Energy Agency, 2021). Clear and up-to-date building codes and standards are critical to ensuring the safety and quality of modular construction (Mohammad-Moradi et al., 2017).

Finally, mass modular construction is driver by a variety of economic, social, environmental, technological, and policy considerations. By addressing these causes and harnessing the benefits of modular building, stakeholders can realize its full potential in meeting the challenges of affordability, sustainability, and efficiency in the construction industry.

2.3.2. Factors that drive the adoption and implementation of mass modular construction

The key drivers of mass modular building have been recognized as cost efficiency, construction speed, sustainability, and quality control. According to a study by Joseph Yel Akok (2017), indicated that the adoption of standardized modules in construction projects can greatly reduce costs by streamlining the design and production processes. This strategy also provides for more efficient material and labor allocation, resulting in speedier project completion timeframes. Furthermore, modular construction has been shown to be more environmentally friendly than traditional construction methods, resulting in lower waste output and energy usage. Quality control is another important driver of mass modular construction, as the factory-controlled production environment promotes consistency and precision in the construction process.

The key factors for the adoption of mass modular construction were investigated in developing countries' design, engineering, and construction industries. The researchers discovered mass modular building in the existing literature and, as a result, compiled a list of the most significant elements driving mass modular construction adoption and implementation, as shown in table 2.1. This classified list is a source of organized information that may be used to propose improvements to the successful implementation of mass modular construction in developing countries.

Table 2. 1: The key drivers of mass modular construction

The key drivers of MMC	**Description**	**References**				
		Bello et al. (2023)	Joseph Yel Akok (2017)	Ismail et al. (2023)	Khan et al. (2022)	Makwana et al. (2017)
Time efficiency	Shorter assembling duration than the conventional method, Compressed project schedules and reduced project completion time.	✓	✓	✓	✓	✓
Waste reduction	Maximizing environmental performance during fabrication, Reducing environmental impact,	✓	✓	✓		✓

	Improved Waste Minimization, Reduction of Energy and Water Consumption.					
Productivity performance	Efficiency in the use of material and labour.	✓	✓	✓	✓	✓
Quality performance	The integrity of Building Design and Construction.	✓	✓		✓	✓
Safety performance	Reduction in site accidents.	✓				
Cost performance	Effective cost planning and control, cost of management, material and labour.	✓	✓	✓	✓	✓
Social performance	Client's demands, Higher Profitability, Accessibility to Prefabricated Materials, Decentralization of Raw Material Supply and Finished Building Material.	✓		✓	✓	
Standardization	Elimination of site malpractices and errors.	✓	✓			
Weather	Weather Efficient against adverse and poor weather.	✓	✓	✓		✓
Good management	Good working collaboration approach, Management of Supply Chain and Logistic, risk management, Procurement Strategy and Contracting.	✓				✓
Land use optimization	Maximization of limited land space, suitability for poor land conditions.	✓				
Operation Efficiency	Proper planning, scheduling and guidelines, understanding the regulations, effective communication, involvement of all team members in the design and construction stage, lean construction and proper coordination.	✓	✓			✓

Source**:** Authors compiled through literature

According to (Bello, Eje, et al., 2023), indicated that numerous factors influence the adoption and implementation of mass modular construction, particularly in developing country. These factors include housing shortages, cost-effectiveness, construction speed, quality control, sustainability and environmental benefits, technological advancements, scalability and flexibility, disaster resilience, government policies and support, and community engagement and local participation.

Rapid urbanization and population grows in emerging countries have resulted in housing shortages, especially in urban areas (Hope, 2008). Modular building can be more cost-effective than traditional construction methods because of reduce material waste, shorter construction timelines, and potential economies of scale (Generalova et al., 2016). Speed of construction, or the ability to construct buildings quickly, is a key driver for mass modular construction acceptance (Elessawy, 2017). Modular construction allows for higher precision and quality control in a regulated factory environment (Mane & Patil, 2015). Sustainability and environmental benefits Modular building frequently leads in decreased material waste, reduce energy usage, and greater environmental performance compared to traditional construction methods (Sullcapuma Morales, 2023). Advancements in design, manufacturing, and construction technologies have made modular construction more feasible and efficient. The use of Building Information Modeling (BIM), advanced manufacturing techniques, and digital fabrication has increased the capabilities and appeal of mass modular construction (Mccoy & Yeganeh, 2021).

Additional characteristics are scalability and flexibility. Modular construction enables scalability, allowing for the rapid replication of ideas and the adaption of building configurations to fit various demand (Generalova et al., 2016). Modular construction can provide a more resilient building solution for disaster-prone areas (Ostadtaghizadeh et al., 2015). Government policies and support, which include government efforts, subsidies, and policies that promote modular building as a solution to meet housing shortages and infrastructure demands, can greatly push its adoption in developing nations (Nikolov, 2020). Modular construction can provide opportunities for local employment, skill development, and community involvement in the construction process, which may appeal to governments and organizations seeking to promote economic development (Shigute, 2022).

Therefore, these factors collectively contribute to increase the adoption and implementation of mass modular construction as a feasible solution for solving housing, infrastructure, and urbanization concerns in developing countries.

Mass modular construction has numerous economic, social, and environmental benefits, particularly in developing country. Economic benefits include cost-effectiveness; mass modular construction can reduce overall construction costs due to factors such as reduced material waste, shorter construction timelines, and potential economies of scale, making housing and infrastructure more affordable for governments, developers, and end-users. Job creation: Modular construction projects can generate employment possibilities, both in the production of modular components and on-site assembly and finishing work, which can help to increase local economic development and skills. Time savings: The speed of construction associated with mass modular techniques can result in significant time savings, allowing for faster occupancy and utilization of housing and infrastructure assets, which is especially important when addressing urgent housing needs and accelerating infrastructure development. Modular building frequently provides higher cost predictability and lower risk of budget overruns than traditional construction methods, which can be useful for project financing and budget planning (Jayawardana et al., 2023).

Some of the social benefits include affordable housing; mass modular building allows for the rapid and cost-effective supply of affordable housing units, which can assist address housing shortages and enhance access to good home for low-income groups. Improved living circumstances: The hastened building of modular housing can help to improve living conditions for vulnerable people, such as those living in informal settlements or natural disaster-prone locations. Modular building projects can promote community engagement, local participation, and skill development, generating a sense of ownership and pride in the built environment. Modular construction can also be utilized to quickly deploy key infrastructure such as schools, healthcare facilities, and community centers, hence enhancing access to vital services for neglected communities (Pero et al., 2021).

Some environmental benefits include reduce material waste, as modular construction often generates reduce material waste than traditional construction methods, contributing to a lower environmental impact and resource conservation. Energy efficiency is achieved through the regulated manufacturing environment of modular construction, which allows for higher precision in building components, resulting in increased energy efficiency and lower operational costs for inhabitants. Sustainable approaches such as mass modular construction can combine sustainable building materials, energy-efficient designs, and green building practices, matching with environmental sustainability goals and lowering construction projects' ecological footprint. Modular construction can enable climate-robust building practices, such as the use of resilient materials and designs that can resist extreme weather events, contributing to community resilience (Loizou et al., 2021).

By providing these economic, social, and environmental benefits, mass modular building presents a compelling answer for developing countries' housing deficits, infrastructure demands, and sustainable development aspirations.

2.3.3. The key drivers of mass modular construction in Ethiopia

According to Bello et al. (2023), study indicated that the previous research on the key drivers of mass modular construction in developing countries, including Ethiopia, found numerous elements that influence modular construction technique acceptance and implementation. Some of the important drivers recognized in developing countries, especially in Ethiopia, are:

Housing demand and urbanization: Rapid urbanization and population expansion in emerging countries, particularly Ethiopia, have increased demand for cheap housing and infrastructure. Mass modular construction can meet this demand by delivering homes and essential facilities in a speedier and more cost-effective manner (Gutu Sakketa, 2023).

Government laws, incentives, and support for novel construction methods can all play a role in increasing the use of mass modular construction in Ethiopia, for example, government programs aimed at addressing housing shortages and fostering sustainable urban growth can influence the use of modular construction techniques (Marichova, 2020).

Advancements in modular building technologies, including as prefabrication, digital design tools, and off-site manufacturing methods, have increased the viability and appeal of mass modular construction. Research on technical breakthroughs and their relevance in the Ethiopian setting can give light on the possibility of widespread adoption (Baghchesaraei et al., 2015).

Cost-effectiveness and affordability: The potential cost reductions associated with mass modular construction compared to traditional construction methods can be a significant drives, particularly in countries with limited resources. Research on the economic viability and cost of modular building in Ethiopia might give insights into its potential impact on the housing market (Lopez & Froese, 2016).

The research has underlined the necessity of skill development and local capacity building in facilitating the implementation of mass modular construction. Training programs, knowledge transfer, and partnerships with local enterprises can propel the use of modular construction systems in Ethiopia (Yeboah, 2023).

Environmental sustainability and resource conservation are becoming more important factors in construction techniques. Research into the environmental benefits of mass modular building and its relevance to Ethiopia's sustainability goals might impact policy decisions and industry practices (Arora et al., 2018).

Disaster resilience and post-disaster rehabilitation are important drivers in disaster-prone areas like Ethiopia, where mass modular construction can quickly provide shelter and infrastructure following natural calamities. Research on the function of modular construction in disaster resilience and post-disaster restoration activities can help inform disaster management techniques (Apurva et al., 2020).

Access to financing and investment for modular construction projects is a significant factor. Research on finance processes, investment options, and financial incentives for modular building in Ethiopia can provide insights into overcoming financial obstacles (Kisi et al., 2019).

As a result of conducting research in Ethiopia and other developing countries, the key drivers of mass modular construction include cost efficiency, construction speed, sustainability, quality control, scalability, flexibility, infection control, and patient comfort. By addressing these drivers, modular construction offers a promising option to meet the growing demand for efficient, sustainable, and high-quality building projects in a variety of industries.

2.4.Challenges faced in the implementation of mass modular construction

2.4.1. Introduction

In developing countries, mass modular construction faces a unique set of challenges that can hinder its development and widespread use. Regulatory limits, insufficient infrastructure, a lack of skilled labor, financial impediments, and cultural preferences are all contributing reasons to these issues. Understanding these problems is vital for properly dealing with them and enabling the successful implementation of mass modular construction in underdeveloped countries (Joseph Yel Akok, 2017).

Mass modular construction has numerous benefits, but its implementation in developing countries presents unique challenges that must be addressed for successful adoption, such as lack of infrastructure, skilled labor shortage, limited financing options, cultural and regulatory barriers, lack of standardization, limited supply chain, public perception, and lack of government support (Kisi et al., 2019).

2.4.2. Challenges faced in the implementation of mass modular construction

The adoption of mass modular construction, particularly in developing countries, may encounter a number of challenges and obstacles. Common challenges include regulatory and policy barriers: Inadequate or outdated building code, zoning regulations, and land use policies may not accommodate or promote the usage of modular construction systems (Fakunle et al., 2020). The adoption and implementation of mass modular construction techniques can be barrier by a shortage of trained workers and specialized training (Hořínková, 2021). Quality control and standards: establishing consistent quality control and adherence to construction standards across modular components and assembly processes is important (Manghani, 2011). Effective supply chain management is crucial for modular construction since it requires coordination among many suppliers, manufacturers, and logistics providers (George & Madhusudanan Pillai, 2019). Financing and investment: Access to financing for modular construction projects can be difficult, especially in developing countries (Salama et al., 2020).

Furthermore, challenges are perceptions and stakeholder buy-in: Overcoming unfavorable perceptions or misconceptions about modular construction among stakeholders, including developers, contractors, and end-users, can be challenging (Dick-Sagoe et al., 2023). Infrastructure and logistics: insufficient infrastructure, such as roads, utilities, and transportation networks, can provide logistical obstacles to the delivery and installation of modular components (Wegrich et al., 2017). Cultural acceptance and aesthetics: modular construction may face resistance in locations where conventional building methods are deeply embedded in the local culture or where there are aesthetic preferences for specific architectural styles (Karthik et al., 2020). Integration with existing construction practices: integrating modular construction into existing construction ecosystems and value chains can be challenging. Environmental and sustainability considerations: It can be tough to ensure that modular construction processes correspond with environmental rules and sustainability goals (Sullcapuma Morales, 2023).

The difficulties encountered with the deployment of mass modular construction were investigated in developing countries. The researchers discovered mass modular building in the existing literature and thus bring together a set of the most important elements that challenges faced adoption and implementation of mass modular construction, as shown in table 2.2.

Table 2. 2: Challenges faced to the successful implementation of mass modular construction

Challenges	**References**				
	Bello, Khan, et al., (2023)	Abdelmageed et al., (2020b)	Kisi et al., (2019)	Thurairajah et al., (2023)	Cantu et al., (2019)
Initial Investment Cost	✓	✓	✓	✓	✓
Logistics and Transportation	✓	✓	✓	✓	✓
Inadequate Coordination, Communication and Planning		✓	✓	✓	✓
Lack of awareness and knowledge		✓			
Site Processes	✓	✓			✓
Lack of design Codes, Standards, Standardization and Supply Chain	✓	✓	✓	✓	✓
Lack of Incentive and Government Support	✓	✓	✓		
Lack of qualified workers (experience and skills)	✓		✓	✓	✓
Limited market demand compared to conventional construction			✓		
Poor integration and interface performance with traditional method			✓		
Lack of government usage of modular construction	✓				
Lack of manufacturing capacity	✓		✓		✓
Lack of regulatory framework for implementation and monitoring	✓		✓		✓
Limited contractors with specialization in modular construction	✓				
Inadequate educational programs on structural and architectural aspects of modular construction	✓				
Lack of technology and testing institute/lab for modules	✓				

Source**:** Authors compiled through literature

Addressing these difficulties in developing countries in general necessitates customized strategies that take into account local legislative frameworks, cultural norms, economic situations, and infrastructure constraints. Collaboration between government agencies, industry players, educational institutions, international organizations, and local communities can assist overcome these barriers and encourage the successful implementation of mass modular building.

2.4.3. Challenges faced in the implementation of mass modular construction in Ethiopia

Implementing mass modular construction in Ethiopia presents numerous hurdles, notably in terms of adapting and scaling this strategy within the country's distinct socioeconomic, regulatory, and infrastructural setting. The key challenges faced in the implementation of mass modular construction in Ethiopia include regulatory and policy constraints, skills and training, supply chain and material sourcing, cultural and community acceptance, infrastructure and connectivity challenges, technology integration, cost management and financing, and quality assurance and certification (Cantu, 2020).

According to Geleta (2019) ; Generalova et al. (2016), indicated that several challenges faced in the implementation of mass modular construction in Ethiopia Initial cost problems include factory expenses, first design costs, and errors; Architectural problems include the impact of manufacturing technology on design, transportation boundaries on architecture, and regional architectural specializations. Architects have a lack of expertise regarding modular constructions, and on-site completion is not viable. Transportation challenges include dimensional and weight barriers based on the mode of transportation, long-distance transportation and the lack of a local factory, state regulations on structure dimensions and strategic issues, negative environmental effects on modules during transportation, and transportable materials; Wrong perceptions among public and real estate market; Integration of advanced software; Redefining the contracts challenges are Design-build, Design-bid-build, Negotiated bid and Certified Modular Architect (CMA); and Supply chain-transportation-onsite assembly management errors. Addressing these challenges and obstacles will be crucial in establishing a robust framework for the successful implementation of mass modular construction in Ethiopia, paving the way for a more efficient, sustainable and cost-effective construction approach in the country (Abdelmageed et al., 2020a).

As a result, the literature identifies a number of challenges to the successful implementation of mass modular building in Ethiopia, including a lack of awareness and comprehension, a scarcity of skilled labor, regulatory limits, sustainability concerns, financial barriers, and logistical challenges. Addressing these obstacles will be critical for Ethiopian mass modular construction to reach its full potential and reap the benefits of cost efficiency, construction speed, sustainability, and quality control.

2.5.Enabling Strategies for implementing mass modular construction

These are used to build a workforce adept in modular construction processes. This includes training for design, fabrication, assembly, and quality control (Odent, 2019). The ideal practice is to design structures with modularity in mind, taking into account issues like unit size, transportation limits, and assembly requirements (Gershenson et al., 1999). Uniformity and prefabrication are ideal practices, as uniformity of modules and components allows for mass production and efficient assembly. Prefabrication in regulated manufacturing environments provides quality while reducing on-site construction time (Zheng et al., 2022). To ensure the fabrication, and assembly of modular structures, rigorous quality control methods must be in place throughout the design, fabrication, and assembly stages (Prístavka et al., 2016). Site management is best practice that is effective. Site management is critical for coordinating the delivery and assembly of modular pieces. This comprises effective logistics, professional labor coordination, and the right storage and handling of modules (Zheng et al., 2022).

To summarize, successful implementation of mass modular construction necessitates a combination of enabling methods and best practices. By using these strategies, stakeholders can overcome challenges, utilize the benefits of modular construction, and contribute to the creation of more sustainable and efficient built environments.

2.5.1. Strategies for overcoming the challenges associated with mass modular construction

Overcoming the difficulties associated with mass modular construction necessitates a holistic approach that addresses structural, logistical, and regulatory issues. Regulatory and policy alignment, or advocating for the development or adaptation of building regulations and codes to explicitly include provisions for modular construction, and engaging with government agencies to streamline permitting and inspection processes for modular projects, are two strategies and best practices that can be used to mitigate challenges and foster successful implementation of mass modular construction. Establish vocational training programs and partnerships with educational institutions to generate a competent workforce capable of utilizing modular construction processes, and provide on-site training. Certification programs for local construction workers. Quality control and standards include implementing strict quality control procedures and ensuring compliance with international construction standards, as well as developing collaborations with certification agencies and quality assurance companies to check modular component quality (Ham & Opdenakker, 2023; Webster, 2016).

Other strategies and best practices include supply chain management, which involves strengthening the local supply chain by developing relationships with dependable suppliers, improving transportation infrastructure, and implementing efficient logistics management systems to ensure timely delivery of modular components. Financing and investment support, which involves collaborating with financial institutions, development banks, and international organizations to develop financing methods specific to modular building projects. Stakeholder involvement and education entails conducting awareness campaigns, workshops, and demonstration projects to educate stakeholders on the advantages of modular building. Infrastructure development involves working with government agencies and infrastructure providers to upgrade road networks, utilities, and transportation systems to simplify the delivery and installation of modular components (Cantu, 2020).

Additional techniques and best practices include cultural integration and aesthetics, which involve local architects and designers in the development of modular construction projects to ensure that designs are consistent with local architectural preferences and cultural norms. Collaboration with the existing construction ecosystem involves fostering partnerships with traditional construction firms, contractors, and suppliers in order to integrate modular construction into existing procedures and harness local expertise. Environmental sustainability stresses the environmental benefits of modular construction, such as decreased waste, energy efficiency, and sustainable material procurement, and applies green building techniques while seeking certification from appropriate sustainability groups (Abdelmageed et al., 2020a; Bello, Eje, et al., 2023).

Implementing these strategies and best practices will enable stakeholders to effectively address the challenges associated with mass modular construction in Ethiopia and other developing countries, ultimately fostering the successful implementation and sustainability of modular construction projects and paving the way for widespread adoption of this innovative construction approach.

2.5.2. Enabling strategies for implementing mass modular construction

The key strategies and best practices for implementing mass modular construction were investigated in developing countries. The researchers discovered mass modular building in the existing literature and so compiled a list of the most notable techniques and best practices for the adoption and implementation of mass modular construction, as shown in table 2.3. This classified list is a source of organized information that may be used to propose improvements to the successful implementation and sustainability of mass modular construction in developing countries.

Table 2. 3: Strategies and best practices for modular construction Implementation

Strategies and best practices that adoption and implementation of MMC	**References**			
	(Esmaeili et al., 2016)	Bello, Ihedigbo, et al. (2023)	Wuni & Shen (2020)	Lafhaj et al., (2016)
Increase of awareness among the professionals and stakeholders		✓	✓	
Creating enabling environment within the industry		✓		
Government participating in the usage of modular construction		✓	✓	
Institutions should be more rigorous in teaching modular construction		✓		
Encourage usage of new and improved technological tools such as Building Information Modeling (BIM), Internet of Things (IOT)		✓		
Professional bodies to trained members and encourage usage of modular construction		✓	✓	✓
Establishing of policies and codes for modular construction		✓	✓	✓
Establishing effective communication in the architecture engineering and construction industry		✓	✓	
Good working collaboration, effective communication, and information sharing among modular construction project participants		✓	✓	

Improved supply chain coordination and management			✓	
Accurate design, early design freeze and timely owner's approval		✓	✓	✓
Fully-integrated approach and involvement of key participants throughout the project			✓	✓
Extensive modular integrated construction project planning, scheduling and control		✓	✓	
Adequate relevant experience and knowledge of contractor, designer, and manufacturer of modular integrated construction projects		✓	✓	
Establishment and communication of a conflict resolution strategy	✓			
A willingness to share resources among project participants	✓		✓	
A clear definition of responsibilities	✓			
A commitment to a win-win attitude	✓			
Regular monitoring of partnering process	✓		✓	

Source**:** Authors compiled through literature

Overall, enabling strategies and best practices for implementing mass modular construction in Ethiopia include a variety of techniques such as knowledge sharing and capacity building, stakeholder involvement and collaboration, and technological adoption and innovation. By using these methods and techniques, stakeholders in Ethiopia's construction industry can overcome obstacles to modular construction implementation and realize the full potential of this revolutionary building style.

Enabling the successful implementation of mass modular construction in Ethiopia necessitates a supporting legislative, regulatory, and incentive environment. The key policies, regulations, and incentives that can facilitate the successful implementation of mass modular construction are modernized building codes and standards, zoning and land use policies, streamlined permitting processes, training and education incentives, research and development funding, public-private partnerships and investment incentives, off-site construction support, local content and material incentives, innovation and technology adoption incentives (Generalova et al., 2016b; Tezera, 2019; Wuni & Shen, 2020).

By implementing these policies, regulations, and incentives, Ethiopia can create an environment conducive to the successful implementation of mass modular construction, fostering a dynamic and efficient construction sector aligned with international best practices in the country's unique socioeconomic and infrastructural landscape.

2.5.3. Effective enabling strategies on mass modular construction

While case studies on mass modular construction in developing countries are limited, some examples and references show effective enabling strategies and activities. These cases demonstrate successful ways, increased usage, or the potential for modular building in developing countries; some case studies are as follows:

Singapore has been a pioneer in advocating the broad usage of modular building. The government has set lofty goals for the adoption of modular technology through incentives, reduced regulations, and a supportive environment for innovation. This has led in a large uptake of modular construction in both public and private sector projects, demonstrating the potential for broad adoption in a developed nation environment and could inspire similar initiatives in developing countries (Siva et al., 2017).

India's inexpensive Housing Initiatives, which are centered on inexpensive housing, have increased the use of modular construction. Projects such as the Mahindra Happinest in Boisar, Maharashtra, demonstrate the effective use of mass modular construction methods to provide low-cost homes. Innovative regulations and financial incentives have been implemented to encourage the use of modular technology to meet the country's housing need (Jain & Bhandari, 2022).

Kenya's Low-Cost Housing Programs are Kenya's government launched low-cost housing programs to investigate the possibilities of mass modular construction as a way to address housing shortages and improve living conditions for its citizens. The incorporation of modular solutions into these efforts indicates the potential of such methods in poor countries (Kieti et al., 2018).

China's Modular Construction Initiatives: Despite not being considered a developing country, China has successfully undertaken large-scale modular construction projects, notably in response to rising urbanization and the demand for inexpensive housing. These programs provide vital insights into how to effectively execute mass modular construction solutions for high-volume, cost-effective construction (Gunawardena & Mendis, 2022).

Ethiopia's low-cost housing programs, which include Addis Ababa's housing sector, have long been a source of concern. For more than a century, the fast expanding Ethiopian capital has been unable to offer appropriate and sufficient accommodation, particularly for its low-income residents. By the early 2000s, Addis Ababa's 4 million residents faced a housing backlog of 233,000 units. In this context, the Ethiopian government partnered with the German Technical Cooperation (GTZ) to address the housing issue through a city-wide mass housing scheme (Weldesilassie & Gebrehiwot, 2017).

These case studies show how enabling policies, financial incentives, and supporting regulatory regimes can promote the effective implementation of mass modular construction in developing countries. They show how modular building may be used to address housing shortages and create sustainable, cheap housing solutions.

According to Geleta (2019), indicated that the modular building system advantage in the building construction industry, in the case of Addis Ababa, could help in the creation of housing affordability by minimizing costs through the advantage of modular buildings in their lightweight design, which reduces foundation costs and the consumption of formwork for molding supports, which reduces the cost of formwork construction. These projects may benefit from a quicker project completion time, allowing for an earlier return on investment in building services and speedier delivery of housing for residents. Although the quality of modular components was marginally interested, in some situations, if components are carefully designed and follow quality guarantees and control processes, it has the advantage of better quality construction of structures that lessen

Rapid urbanization and population increase in developing countries such as Ethiopia have created a greater demand for affordable and sustainable housing alternatives. Mass modular construction has emerged as a promising solution to satisfy this demand. However, its successful implementation in the Ethiopian setting confront significant hurdles and require enabling strategies (T. Dube et al., 2021; Mezgebo, 2021; Moshinsky, 2015). As a result, there is a need to conduct a thorough analysis of the key drivers, challenges, and enabling strategies for the successful implementation of mass modular construction in Ethiopia, as well as to create a strategies that can guide policymakers, developers, and other stakeholders in effectively implementing mass modular construction projects in similar developing countries.

Ethiopia's construction industry has various obstacles, including a lack of affordable housing, inefficient construction processes, and limited infrastructural development. In response to these issues, mass modular construction is gaining popularity as a viable solution to the housing scarcity and increased construction efficiency. However, the successful deployment of mass modular construction in Ethiopia is hampered by a number of technological, legal, and capacity constraints. As a result, it is critical to identify and examine the primary drivers of mass modular construction in Ethiopia, as well as the problems and barriers to its implementation. Furthermore, building enabling policies for the long-term viability of mass modular construction in Ethiopia is vital for promoting its sustainable acceptance and integration into the construction industry (Lafhaj et al., 2016).

Despite the potential benefits of mass modular construction in Ethiopia, there are several challenges and obstacles to its implementation. Technical obstacles, such as a lack of knowledge and adequate technology, may hinder the widespread implementation of modular construction. Economic problems, such as high initial prices and affordability concerns, provide substantial impediments to the implementation of mass modular construction projects. Furthermore, social and cultural elements such as acceptance and perception may have an impact on the viability and acceptability of mass modular construction in Ethiopia. Therefore, it is necessary to analyze these issues and constraints in order to design methods to solve them and allow the successful implementation of mass modular construction in Ethiopia (Abdelmageed et al., 2020a; Abebe, 2020).

While mass modular building has the ability to meet Ethiopia's housing and infrastructure needs, there is a lack of understanding of the enabling strategies and best practices for its implementation. Analyzing successful case studies and best practices from other developing countries is critical for identifying the tactics used for effective mass modular construction implementation. Furthermore, it is necessary to investigate the legislative and policy frameworks that can facilitate the acceptance and implementation of mass modular construction in Ethiopia.

Furthermore, knowing the role of stakeholders, such as the government, business sector, and local communities, as well as their participation in the implementation process, is critical for Ethiopia's successful mass modular construction adoption. Hence, there is a need to identify and assess enabling strategies and best practices for adopting mass modular building in Ethiopia (Abdelmageed et al., 2020a; H. C. C. and A. C. Cantu, 2020; Ham & Opdenakker, 2023; Musa et al., 2016).

The main problem addressed by this research is the lack of a comprehensive framework that integrates the key drivers, challenges, and enabling strategies for the successful implementation and sustainability of mass modular construction in developing countries, with a focus on Ethiopia. This framework will provide practical guidance for policymakers, practitioners, and other stakeholders to effectively promote and support the adoption of mass modular construction in the Ethiopian construction industry.

Research into mass modular construction in developing country is gaining traction as a potential solution to housing shortages, fast urbanization, and infrastructure issues. Several studies have investigated the benefits, constraints, and prospects of implementing mass modular construction in developing countries (Joseph Yel Akok, 2017). Some significant themes and conclusions from prior study include affordable housing, with many studies focusing on the possibility of mass modular building to provide affordable housing options in developing countries. Research has emphasized the capacity of prefabricated modules to minimize building costs, reduce project deadlines, and improve access to decent housing for low-income communities (Pero et al., 2021).

The second fast urbanization: With the rapid growth of urban areas in emerging countries, academics have investigated how mass modular construction might enable the speedy and efficient creation of residential and commercial buildings to accommodate expanding urban populations (Gutu Sakketa, 2023). The third infrastructure development is mass modular building, which has been explored in the context of infrastructure development, such as schools, healthcare facilities, and community centers. Research has highlighted the potential of prefabricated modules to speed the supply of key infrastructure in underserved areas (Joseph Yel Akok, 2017). The fourth aspect is local manufacturing and employment: various studies have looked into the possibility of mass modular building to boost local manufacturing industries and offer job possibilities in underdeveloped countries. This includes exploring the viability of setting up modular building facilities and training local personnel in module production and assembly (Kantamneni & Dr K Chandramouli, J Sree Naga Chaitanya, 2021).

The fifth disaster resilience: study has looked into how mass modular construction might help with disaster-resilient housing and infrastructure solutions in natural disaster-prone areas. This involves evaluating the usage of prefabricated modules for quick post-disaster restoration initiatives (Keating et al., 2017). Finally, studies have looked at the legislative, regulatory, and institutional issues that can either support or impede the adoption of mass modular building in developing nations. This includes looking into building rules, land use regulations, and government incentives for modular construction projects (May, 2010).

Overall, recent research on mass modular construction in developing countries has demonstrated its ability to address a variety of socioeconomic and environmental issues. However, it is acknowledged that further research, pilot projects, and capacity-building activities are required to fully realize the benefits of mass modular construction in developing nations. As the area evolves, continuous study will be crucial in determining the application and impact of mass modular construction in underdeveloped countries.

2.6.Gap of Study

The study's main research gaps include a lack of understanding of the key drivers of mass modular construction in the Ethiopian context, including the driving forces and opportunities that encourage its adoption, as well as a lack of empirical research on the specific drivers and their relative importance in the Ethiopian context, as well as a lack of data on demand and market potential for mass modular construction.

Insufficient awareness of the unique problems faced by the Ethiopian construction industry in implementing modular construction as well as limited research on the barriers related to technology, skills, infrastructure, and regulation in the Ethiopian context.

There is a lack of comprehensive analysis of enabling strategies and best practices for implementing mass modular construction in Ethiopia, including successful case studies, regulatory and policy, and stakeholder involvement, as well as a lack of tailored strategies and best practices specifically designed for the Ethiopian context, as well as limited knowledge on how to adapt successful strategies from other countries to the Ethiopian environment.

There is a lack of strategies for successful mass modular construction implementation, as well as a comprehensive strategy that integrates the key drivers, challenges, and enabling strategies for mass modular construction in Ethiopia. There is also a lack of research on the long-term sustainability and performance of modular buildings in the Ethiopian climate and conditions, which uses the fuzzy TOPSIS method to prioritize key factors and strategies.

Additional research gaps include stakeholder views, which refer to the limited study on the perceptions, attitudes, and roles of key stakeholders such as government agencies, industry professionals, and potential users. Cost-benefit analysis reveals insufficient evidence on the economic sustainability and cost-effectiveness of mass modular construction in Ethiopia when compared to traditional construction methods. Environmental impact refers to a lack of research on the environmental benefits and potential problems of mass modular construction in Ethiopia. Social implications include a limited understanding of the social impacts of mass modular construction on communities, jobs, and cultural heritage.

Addressing these research gaps would help to improve our understanding of the possibilities and constraints of mass modular construction in Ethiopia. It would also provide useful information for building effective strategies to ensure its successful implementation and sustainability.

As a result, the goal of this research is to address this gap by analyzing the key drivers of mass modular construction in Ethiopia, investigating the challenges to its successful implementation, evaluating enabling strategies and best practices, These objectives would help to close the research gap by giving a detailed understanding of the factors influencing mass modular construction in Ethiopia and making practical recommendations for its successful implementation

CHAPTER THREE
RESEARCH METHODOLOGY

3.1.Introduction

This chapter covers the methodology utilized in the research investigation. This chapter is organized as follows: a brief introduction to the study area, research design, population and sampling frame of the study, sampling technique, sample size determination, data collection method, the process of data analysis techniques, questionnaire reliability and validity tests, and ethical considerations. The acquired data was analyzed using a fuzzy TOPSIS-approach, which is a fuzzy TOPSIS (Technique for Order Preference by Similarity to Ideal Situation) that may be used to compare various options to the chosen criteria.

3.2.Study Area

The study focuses on the construction industry in Ethiopia, specifically Addis Ababa. The research focuses on the potential for mass modular construction to address housing and infrastructure challenges in Ethiopia, Addis Ababa. The study looked at the current condition of mass modular building in Ethiopia, including key drivers, challenges, enabling strategies, and best practices for successful implementation. By addressing the research objectives, the study seeks to analyze the drivers, challenges, and enabling strategies that influence the effective implementation of mass modular construction in Ethiopia, with the potential to be extended to other developing nations facing comparable issues. As a result, the research technique used a quantitative research approach, which is a research strategy that is suited for this study. Figure 3.1 depicts the spatial description of the study region graphically in the context of the Addis Ababa map.

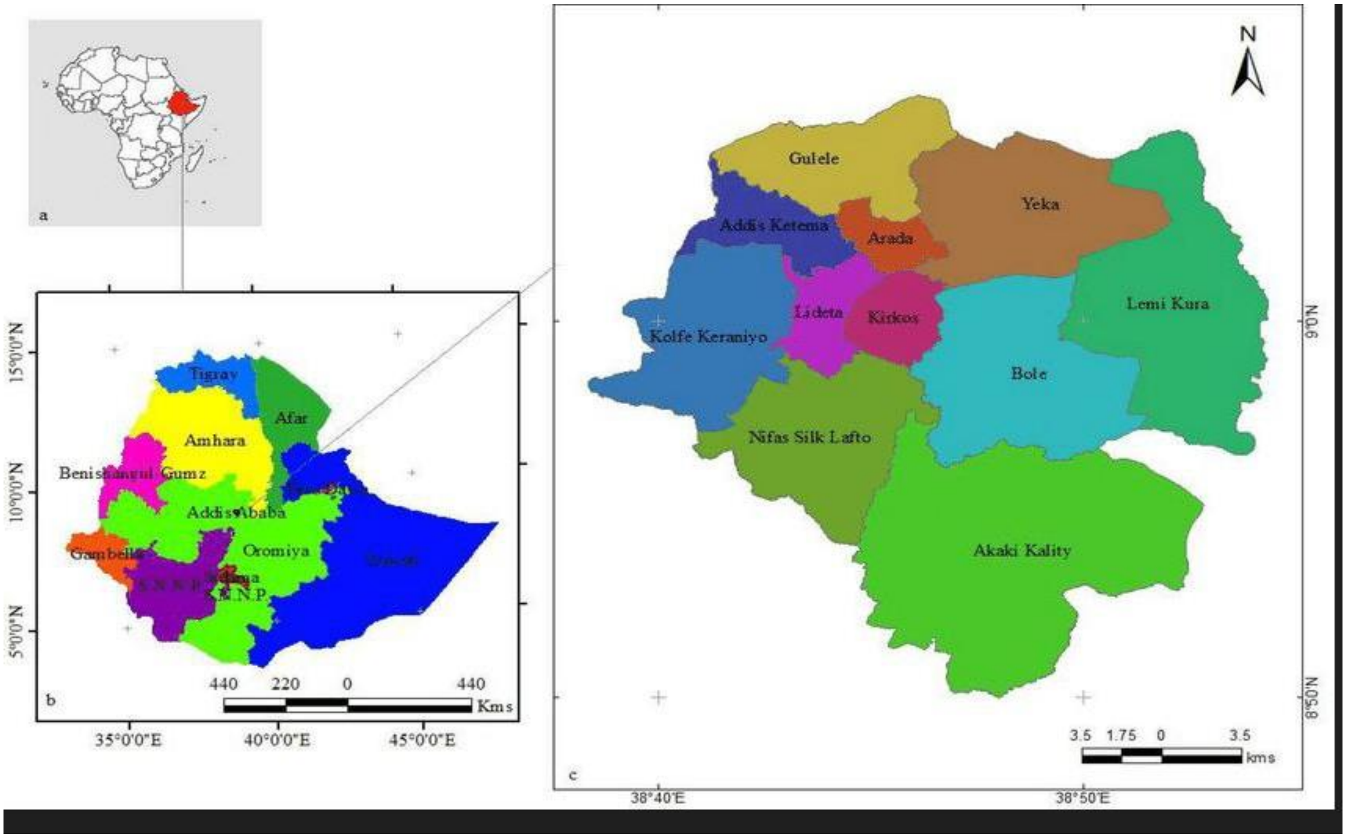

Figure 3. 1: Map of Addis Ababa

Source: Addis Ababa city Municipal

3.3.Research design

The research approach for this study was used a quantitative methods to gather data and analyze the key drivers, challenges, enabling strategies, and best practices for the successful implementation of mass modular construction in Ethiopia, Addis Ababa. The research design refers to the specific plan or blueprint that a researcher uses to execute their research approach. It involves the selection of research methods, data collection techniques, and data analysis procedures that would use to answer the research questions. The research design for this study was used descriptive and explanatory research design.

A descriptive research design was employed to collect information, with a focus on analysis and investigating the key driver associated with mass modular construction in Addis Ababa. The paper attempts to provide a complete overview of the causes, difficulties, and enabling methods for mass modular construction in developing countries, with a particular emphasis on Addis

Ababa. The use of a fuzzy TOPSIS-approach to prioritize and evaluate these factors, as it seeks to provide a detailed and systematic analysis. Overall, the study seeks to analyze the key driver, challenges, and enablers that determine the successful implementation of mass modular construction in Addis Ababa

3.4.Population and Sampling Frame

Population refers to the entire group of individuals or objects that meet a certain set of criteria and are of interest to the researcher. The target populations frame consists of 21 mass modular construction projects for this research study were modular construction industry in Ethiopia, including government officials, developers, architects, engineers, and other relevant professionals involved in the implementation of mass modular construction projects.

A sample frame is a list or representation of the population from which a sample was selected for the research project. The sampling frame for this research study would cover Ethiopia's modular construction industry, such as government officials, developers, architects, engineers, and other relevant experts involved in the implementation of large-scale modular construction projects. This was also included Addis Ababa-based professionals and researchers in modular construction and sustainable development. To ensure that the research findings are comprehensive and applicable to the broader context of Ethiopia's modular construction industry, the sampling frame needed to be diverse and representative of the various perspectives and experiences related to mass modular construction in Addis Ababa.

3.5.Sampling Technique

Sampling is a technique that allows researchers to infer information about a population based on the results of a subset of the population, rather than having to analyze every person. A stratified sampling technique was best suited for a quantitative method research design aimed at investigating the drivers, challenges, and enabling strategies that influence the successful implementation of mass modular construction in Ethiopia, specifically in Addis Ababa. In this study, the size of target population frame consists of a total 1248 mass modular construction professional i.e. for government officials = 437, for engineers = 374, for developers = 187 and for architects = 250 are considered to be in the population frame.

The stratified sampling technique is a probability sampling technique that divides the field of modular construction into strata based on factors such as government officials, developers, architects, engineers, and other relevant experts involved in the implementation of large-scale modular construction projects randomly choose participants from the modular construction industry within each stratum to ensure appropriate representation. It divides populations into strata depending on key criteria and then randomly selects participants from each stratum.

3.6.Sample size determination

Sample size determination is the procedure of picking representative units of a construction party for a study in a research investigation. It is critical to ensure that the sample size is sufficient to produce trustworthy and accurate results for the study. The sample size of the overall sampling frame was calculated to ensure the required number of respondents (representatives). The data collected using this technique should be more representative and accurate.

Therefore, this research paper was considers the respondents as sample representative; the following equation 3.1 was used to determine the sample size of a simple random sampling technique from target population frame (Lombeso, 2018):

$$n = \frac{NZ^{2}Pq}{e^{2}(N-1)+Z^{2}Pq} \qquad 3.1$$

Where; n is the desired sample size, N is the size of target population, Z is the standard normal deviate usually set at 1.645 for 90% confidence level, P is a proportion of target population have a specific characteristics (if no estimate available set at 50%), q is one minus P and e is acceptable sample error.

To calculate the sample size of respondents using equation 3.1, as shown below:

$$n = \frac{NZ^{2}Pq}{e^{2}(N-1)+Z^{2}pq} = \frac{1248(1.645)^{2}(0.5)(0.5)}{(0.1)^{2}(1248-1)+(1.645)^{2}(0.5)(0.5)} \approx 68$$

Therefore, the sample size is selected 68 respondents.

The sampling frame for this stratified sampling technique would comprise a list of all government officials, developers, architects, and engineers in the population under consideration. This list could come from professional directories, government bodies, or other sources.

To conduct a survey of professionals in the mass modular construction business, the researchers decide to divide the population by profession (government officials, developers, architects, and engineers). The researcher determined the sample size based on the population proportions for these professions, which are 437, 374, 187 and 250, respectively. To guarantee good representation of respondent proportions, the sample size of 68 was determined as follows:

Government officials’ $\frac{(68)(437)}{1248} = 24$ respondents

Developers: $\frac{(68)(374)}{1248} = 20$ respondents

Architects: $\frac{(68)(187)}{1248} = 10$ respondents

Engineers: $\frac{(68)(250)}{1248} = 14$ respondents.

By selecting respondents at random from each profession, you ensure that the sample accurately represents the population's professional composition and gives trustworthy estimates for each.

3.7.Data Collection Method

This research was conducted using a variety of data collection approaches. Both primary and secondary data have been obtained. The researcher gets the primary data from the respondents via a self-administered questionnaire. To investigate the drivers, challenges, and enabling strategies that influence the successful implementation of mass modular construction in Addis Ababa, the Fizzy TOPSIS approach was used. A combination of qualitative and quantitative data collection methods has been ideal.

The researcher collects secondary data by gathering information from published and unpublished documents, maps, plans, standard documents, statistical information, and other related materials obtained from various sources. The researcher gathered secondary data by reviewing relevant literature, and reports on the key drivers, challenges, and enabling strategies of mass modular construction in developing countries to augment the primary data gathered via questionnaires.

A questionnaire was used as the primary technique for gathering primary data from the target participants. The following data collection methods were used:

3.7.1. Questionnaires

The questionnaire has two sections. The first portion of the questionnaire collects information about the respondents' backgrounds. The second part question number-1 of the questionnaire gathers information about the key drivers of mass modular construction. The second part question number-2 of the questionnaire gathers information about the challenges to the successful implementation of mass modular construction. The second part question number-3 of the questionnaire gathers information about the enabling strategies and best practices for implementing mass modular construction in Addis Ababa.

3.8.Data analysis Method

To meet the research objectives, the Fizzy TOPSIS technique was utilized to prioritize the drivers, challenges, and enabling solutions for mass modular construction in developing countries, notably Ethiopia. This strategy employs a multi-criteria decision-making technique to assist in prioritizing the various elements based on their significance and impact on the success of mass modular construction. To design a framework utilizing the Fizzy TOPSIS approach, the following data analysis approaches are appropriate:

Quantitative analysis is the use of statistical methods such as regression analysis, correlation analysis, and factor analysis to analyze quantitative data from structured questionnaires in order to identify the relationships between different factors and the challenges they pose to mass modular construction success.

A comparative analysis strategy was utilized to evaluate the prioritized elements revealed by the Fizzy TOPSIS approach to current enabling strategies or best practices in other countries in order to uncover parallels, variations, and possible opportunities for adaption in Addis Ababa.

3.8.1. Descriptive analysis for importance weighting of mass modular construction criteria’s

In this study, descriptive data analysis was used to analyze respondents' demographics (respondent's profile), which included their educational background, occupational title, professional work experience, professional position, and understanding of mass modular construction using frequency, charts, and percentages.

In this study, descriptive data analysis were used to determine the importance of key drivers of mass modular construction, the challenges to effective implementation of mass modular construction, and the enabling strategies for implementing mass modular construction. A questionnaire was distributed, and respondents were asked to rate the implementation importance of the 12, 16, and 19 mass modular construction criteria on a five-point Likert scale, as well as the relative importance of each criterion in comparison to the other criteria and its level of implementation. The five-point scale approach was used for this purpose to make judging easier, and the analysis was based on simple fuzzy set computations.

3.8.2. Fuzzy set for mass modular construction

A fuzzy set is a class of items having varying degrees of membership. Such a set is characterized by a membership (characteristic) function that assigns each object a grade of membership ranging from zero to one (Zadeh, 2014).

A questionnaire was used to collect input data from key drivers of mass modular construction in Addis Ababa, and respondents were asked to answer the implementation importance weighting of 12 criteria in a linguistic form using a 5-point fuzzy importance weighting scale, as shown in table 3.1.

Table 3. 1: Fuzzy fiction scale of the key drivers of MMC

Linguistic scales	Symbol	Number	Triangular Fuzzy Number
Not Important	NI	1	(1, 1, 3)
Slightly Important	SI	2	(1, 3, 5)
Moderately Important	MI	3	(3, 5, 7)
Important	I	4	(5, 7, 9)
Extremely Important	EI	5	(7, 9, 9)

Source: (Kore et al., 2017; Sakib & Arif-uz-zaman, 2013)

A questionnaire was used to collect input data on the challenges to the successful implementation of mass modular construction in Addis Ababa, and respondents were asked to answer the implementation importance weighting of 16 criteria in a linguistic form using a 5-point fuzzy importance weighting scale, as shown in table 3.2.

Table 3. 2: Fuzzy fiction scale of challenges to the successful implementation of MMC

Linguistic scales	Symbol	Number	Triangular Fuzzy Number
Very Low Challenge	VLC	1	(1, 1, 3)
Low Challenge	LC	2	(1, 3, 5)
Moderately Challenge	MC	3	(3, 5, 7)
High Challenge	HC	4	(5, 7, 9)
Very High Challenge	VHC	5	(7, 9, 9)

Source: (Kore et al., 2017; Sakib & Arif-uz-zaman, 2013)

A questionnaire was used to collect input data on the enabling strategies and best practices for implementing mass modular construction in Addis Ababa, and respondents were asked to answer the implementation importance weighting of 19 criteria in a linguistic form using a 5-point fuzzy importance weighting scale, as shown in table 3.3:

Table 3. 3: Fuzzy fiction scale of enabling strategies & best practices for implementing MMC

Linguistic scales	Symbol	Number	Triangular Fuzzy Number
Not Effective	NE	1	(1, 1, 3)
Slightly Effective	SE	2	(1, 3, 5)
Moderately Effective	ME	3	(3, 5, 7)
Effective	E	4	(5, 7, 9)
Extremely Effective	EE	5	(7, 9, 9)

Source: (Kore et al., 2017; Sakib & Arif-uz-zaman, 2013)

3.8.3. Integration of fuzzy TOPSIS method to prioritize mass modular construction

According to Karimi et al. (2012) ; Shamsuzzoha et al. (2021), the studies have shown that incorporating the Fuzzy TOPSIS method into the strategic development for mass modular construction can significantly improve the decision-making process by providing a structured, systematic approach that accommodates uncertainty and imprecise data, which are common in complex construction decision-making scenarios. Let's look at how the Fuzzy TOPSIS method can be used into the framework design for mass modular construction.

The key integration steps are (Jaber et al., 2021; Song et al., 2019):

Step 1: Identification of decision criteria

Step 2: Establish Fuzzy Sets and Membership Functions

Step 3: Data collection and pairwise comparison.

Step 4: Calculate Ideal and Negative-Ideal Solutions.

Step 5: Determine the Closeness to Ideal Solution

Step 6: Ranking and prioritization

The benefits of integration include improved decision modeling: incorporating the Fuzzy TOPSIS method allows for the systematic evaluation and prioritization of enabling strategies, taking advantage of the method's ability to handle imprecise, vague, and uncertain information found in complex decision-making settings. Balanced trade-offs: The method facilitates the balanced assessment of strategies across several parameters, allowing for informed trade-offs based on relative performance, which is critical in the context of mass modular building. Fuzzy TOPSIS enables a clear and structured prioritization framework, helping to make educated judgments about the selection and implementation of enabling techniques within mass modular construction projects (Jumarni & Zamri, 2018).

By including the Fuzzy TOPSIS technique into the framework development process, decision-makers may effectively traverse and manage the inherent ambiguity and uncertainty in prioritizing enabling options for mass modular building, promoting well-informed and sound decision-making.

3.8.4. Fuzzy TOPSIS method data analysis

The fuzzy decision matrix must be generated based on the linguistic factors chosen for ranking the choices in relation to expert criteria. Linguistic variables are adjectives that refer to parameters or alternatives. A fuzzy number is a convex and normal subset of the discourse universe (x). In any linguistic scale, linguistic variables are represented by a set of fuzzy numbers. These fuzzy numbers, like the one depicted in the universe of discourse x, have both convexity and normalcy features. The following steps might be taken to build data analysis methodologies for this study on mass modular construction in underdeveloped nations utilizing a fuzzy TOPSIS approach: (Ashrafzadeh et al., 2012):

Step 1: Understand the Fuzzy TOPSIS approach, which is based on the Fuzzy Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method. This method is used to select the best option from a list of alternatives by taking into account both the positive and negative elements of each.

Step 2: Define the criteria, or establish the criteria used to assess the primary drivers, problems, enabling strategies, and best practices for mass modular construction in poor nations.

Step 3: Create a choice matrix using the selected criteria and the performance scores of each alternative (e.g., drivers, challenges, enabling strategies). To account for data uncertainty and imprecision, the ratings should be assigned as fuzzy values. The linguistic terms are translated into triangular fuzzy integers to generate the fuzzy decision matrix for each choice.

Step 4: Create a fuzzy combined decision matrix that incorporates the defined criteria and the performance ratings of each alternative using the obtained combined triangular fuzzy numbers.

$X = \left(a_{ij}, b_{ij}, c_{ij}\right) \quad where, a_{ij} = \min(a_{ij}^k), \quad b_{ij} = \frac{1}{k}\sum_{k=1}^{k} b_{ij}^k \quad and\ c_{ij} = \max\left(c_{ij}^k\right)$ and k is number of respondents.

Step 5: Calculate the weighted normalized decision matrix, which normalizes the decision matrix to ensure that all criteria are on the same scale before assigning weights to each criterion based on their relative importance. The weighted normalized fuzzy decision matrix can be calculated using expert judgment or analytical methods by:

$$r_{ij} = \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*}\right) and\ c_j^* = \max\left(c_{ij}\right)$$

Step 6: Determine the fuzzy positive ideal solution (FPIS) and the fuzzy negative ideal solution (FNIS). Determine the FPIS and FNIS for each criterion, which represent the best and worst performance levels for each.

$$A^+ = \left(r_1^+, r_2^+, r_3^+\right), \quad where\ r_j^+ = \max\left(r_{i3}^+\right)\ and \quad A^- = \left(r_1^-, r_2^-, r_3^-\right), \quad where\ r_j^- = \min\left(r_{i3}^-\right)$$

Step 7: Calculate the fuzzy closeness coefficient, which is the distance between each alternative and the FPIS and FNIS in order to determine their relative proximity to the optimal solution.

This will help to rank the options based on their overall performance. Calculate the Euclidean distance between each choice from fuzzy positive (A+) and negative (A-) using

$$d_i^{+} = \sqrt{\frac{1}{3}(a_i - a_1)^2 + (b_i - b_1)^2 + (c_i - c_1)^2} \quad where,\ A^{+} = (a_1, b_1, c_1)$$

$$d_i^{-} = \sqrt{\frac{1}{3}(a_i - a_1)^2 + (b_i - b_1)^2 + (c_i - c_1)^2} \quad where,\ A^{-} = (a_1, b_1, c_1)$$, then calculate the closeness coefficient CC_i of the alternatives are calculated using $CC_i = \frac{d_i^{-}}{d_i^{+} + d_i^{-}}$

Step 8: Rank the alternatives (key drivers, challenges, and enabling strategies) according to their fuzzy closeness coefficients. The option with the highest proximity coefficient is considered the best answer.

Step 9: Interpret and analyze the fuzzy TOPSIS analysis results to determine the most important drivers, challenges, enabling strategies, and best practices for the successful implementation of mass modular construction in developing countries. Use these insights to look into the factors that determine the effective deployment of mass modular construction procedures in developing countries.

Researchers used a combination of data analysis tools to explore the drivers, challenges, and enabling strategies that influence the successful implementation of mass modular construction in developing countries, particularly Ethiopia.

3.9.Validity and Reliability

Validity and reliability are terms used to assess the quality of research, indicating how well a method, technique, or test assesses something. According to Stilwell & Hoskins (2013), According to the study, reliability and validity are the two most important criteria for evaluating data quality control, with validity presuming reliability. Validity refers to the accuracy or truthfulness of a study's findings, whereas reliability refers to their consistency or stability across time and in different contexts. Validity and dependability are critical factors in study design and data analysis.

3.9.1. Validity of the research method

Validity in research refers to the extent to which a study accurately measures what it is intended to measure, and the validity of questionnaire data is heavily influenced by respondents' capacity and desire to offer the requested information. The questionnaire was adapted from evaluated literature and similar study instruments and tailored to the current research context. Furthermore, the customized questions were pilot tested by advisers, professionals in the field, and specialists to ensure validity. Overall, the researchers hope to increase the validity of their studies by using suitable measures, controlling for confounding variables, and ensuring that their findings can be applied to other populations or contexts.

In this way, the study was structured to clearly and accurately answer the desired purpose (research question). The instrument's similarity to other mass modular construction measurement scales, detailed reviewed literatures of the constructs/concepts identified by the variables in the two parts of the questionnaires, advisor's review, university instructors' comments, and subsequent steps in the process that follow a formal statistical/scientific approach in answering the research questions ensured that the study approach and the measurement instrument fulfilled all of the constructs.

To validate the results of the investigation on the drivers, challenges, and enabling strategies influencing the successful implementation of mass modular construction in Ethiopia, Addis Ababa, the researcher can employ triangulation. Triangulation involves using multiple sources of data, methods, and perspectives to corroborate and validate the findings of a study. Triangulation which is involves multiple researchers or experts in the study to provide diverse viewpoints and interpretations of the data. By having different researchers independently analyze the data and compare their findings, the researcher can reduce bias and enhance the credibility of the results. By employing triangulation techniques, the researcher can strengthen the validity and reliability of the results on the drivers, challenges, and enabling strategies influencing the successful implementation of mass modular construction in Ethiopia.

3.9.2. Reliability of Questionnaire

A questionnaire's dependability refers to its consistent and stable performance throughout time. A trustworthy questionnaire produced consistent answers whether distributed to the same group of people at different times or by different researchers. To ensure questionnaire reliability, employ standardized questions, clear instructions, and a consistent format. Additionally, pilot testing the questionnaire on a small sample would aid in identifying any issues with the questions or format before administering it to a larger sample. Overall, a valid questionnaire is required to collect accurate and trustworthy data for research purposes.

Cronbach's alpha coefficient, a statistical measure used to determine the internal consistency of questionnaire reliability, was examined. It illustrates how closely connected a group of elements is, as well as how they measure the same underlying construct. A high Cronbach's alpha coefficient (usually greater than 0.7) indicates that the questionnaire is reliable and consistent in measuring the anticipated outcomes. However, it is crucial to emphasize that reliability is only one component of questionnaire validity; other aspects such as content and construct validity were also evaluated.

Data acquired from the respondent's profile of the questionnaire reliability is test participants' personal qualities regarding the test environment and their condition can contribute to whether or not a test is effective. The sampling approach is that the researcher bases the target population selection on the informant's dependability and competency. This is a valid concern, particularly for key informants, on whom most of the data quality depends.

Data obtained from the key drivers of mass modular construction of the questionnaires, internal consistency reliability is verified by Cronbach's alpha coefficient in rated on a five-point Likert scale of importance weighting, which included 1 = Not Important (NI), 2 = Slightly Important (SI), 3 = Moderately Important (MI), 4 = Important (I) and 5 = Extremely Important (EI), and The data obtained from the challenges to the successful implementation of mass modular construction of the questionnaires, internal consistency reliability is verified by Cronbach's alpha coefficient in rated on a five-point Likert scale of importance weighting, which included 1 = Very Low Challenge (VLC), 2 = Low Challenge (LC), 3 = moderately Challenge (MC), 4 = High Challenge (HC) and 5 = Very High Challenge (VHC) In addition to the data collected from the enabling strategies and best practices for implementing mass modular construction of the questionnaires, internal consistency reliability is also tested by Cronbach's alpha coefficient in rated on a five-point Likert scale of importance weighting, which included 1 = Not Effective (NE), 2 = Slightly Effective (SE), 3 = Moderately Effective (ME), 4 = Effective (E) and 5 = Extremely Effective (EE). Cronbach's alpha values were used to assess the reliability of each construct's pieces. Cronbach's alpha only needs one test administration to provide a unique estimate of the reliability.

The test of reliability, the equation 3.6 is used to determine the Cronbach's alpha as shown below (Namdeo & Rout, 2016):

$$\alpha = \left(\frac{k}{k-1}\right)\left(\frac{{S_T}^2 - \sum {S_i}^2}{{S_T}^2}\right) \quad \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \quad 3.6$$

Where; α is the Cronbach alpha coefficient, K is the number of items, S_i^2 is the variance of i^{th} item and S_i^2 is the variance of total score formed by summing items.

Responses of Reliability Analysis: Prior to completing an analysis based on the questionnaire responses, Cronbach analysis was performed to determine the internal consistency of the questions using a five-point Likert scale. The Cronbach Alpha test that demonstrates the reliability of the questionnaire and the results of the reliability test that was conducted on the key drivers of mass modular construction, the challenges to the successful implementation of mass modular construction, and the enabling strategies and best practices for implementing mass modular construction in Addis Ababa is represented in the Table 3.5, as shown below.

Table 3. 4: Result of Reliability test

Reliability Statistics	Cronbach's Alpha	No of Items
The key drivers of mass modular construction	0.796	12
The challenges to the successful implementation of mass modular construction	0.756	16
The enabling strategies and best practices for implementing mass modular construction	0.926	19
Overall	0.844	47

Source: Own survey data analysis

The findings show that the 12 key drivers of mass modular construction in Addis Ababa are correlated. There is internal coherence among the elements. Because the data collected was based on five Likert-scales, Cronbach's Alpha was used to ensure the research's reliability, and all components were high or close to one. The aggregate Cronbach Alpha value for the 12 items is 0.796, indicating that the data is very reliable.

The findings show that the 16 challenges to the successful implementation of mass modular construction in Addis Ababa are connected. There is internal coherence among the elements. Because the data collected was based on five Likert-scales, Cronbach's Alpha was used to ensure the research's reliability, and all components were high or close to one. The aggregate Cronbach Alpha value for the 16 items is 0.756, indicating that the data is very reliable.

The findings show that the 19 items in the enabling strategies and best practices for undertaking mass modular construction in Addis Ababa are connected. There is internal coherence among the elements. Because the data collected was based on five Likert-scales, Cronbach's Alpha was utilized to ensure the research's reliability, and all components were high or close to one. The aggregate Cronbach Alpha rating for the 19 items is 0.926, indicating great data dependability. As a result, the researchers conclude that both the test and the questions were reliable.

3.10. Ethical consideration

This study raised some ethical concerns. When designing and administering a questionnaire, it is critical to consider ethical standards such as informed consent, confidentiality, and privacy. The research participants will be fully informed about the study's goal, their rights, and the use of their data. Additionally, research participants will be able to decline participation or withdraw from the study at any moment without penalty. It is also critical to safeguard the confidentiality and privacy of research participants by securely storing data and using anonymous or pseudonymous identifiers. Finally, researchers will ensure that the study's potential benefits balance the risks or harm to participants.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1. Introduction

The findings and discussion are the most important aspects of the study. This topic is based around the research purpose and offers the findings. The key findings were directly related to an investigation into the causes, difficulties, and enabling strategies that influence the effective deployment of mass modular building in developing nations, notably Addis Ababa. The material gathered through survey questionnaires and case studies is examined within the context of the study's aims.

The Fizzy TOPSIS approach was used to prioritize the drivers, challenges, and enabling solutions for mass modular construction in Addis Ababa, with the goal of ensuring successful implementation. As a result, interpretations and comments were offered based on the findings. As a result, the purpose of this issue is to analyze the significance of the findings in relation to the research objectives outlined in the introduction, and the results are provided concurrently based on general information about the respondents and the mass modular construction in Addis Ababa.

Respondents received 81 questionnaires aimed at better understanding the causes, obstacles, and enabling strategies that influence the effective implementation and sustainability of mass modular building in Addis Ababa. However, only 68 surveys were gathered, with an 84% response rate; case studies and pertinent materials were also analyzed. Given the difficulty of collecting data in large modular building professions, an 84% response rate was relatively very good, as shown in Table 4.1 below:

Table 4. 1: The distribution sample respondents' rate

No of distributed questionnaire	No of returned Responses	% of returned Responses
81	68	84%

Source: Own survey data analysis

4.2. Demographical Profile of Respondents

This section summarizes the demographics of the respondents, including their occupation title, work experiences, professional position, education level, and understanding of mass modular building. According to frequency table 4.2, 18 (26.5%) of all respondents worked as directors of housing, 31 (45.6%) as directors of design and construction, 15 (22.1%) as directors of physical plant, and 4 (5.9%) as other jobs. The occupation-related results are shown in table 4.2 below.

Table 4. 2: Official occupational title

Official occupational title	Frequency	Percent	Valid %	Cumulative %
Director of Housing	18	26.5	26.5	26.5
Director of Design and Construction	31	45.6	45.6	72.1
Director of Physical Plant	15	22.1	22.1	94.1
Other	4	5.9	5.9	100.0
Total	68	100.0	100.0	

Source: Own survey data analysis

The frequency According to Table 4.3, 13 (19.1%) of respondents have less than 5 years of work experience, 26 (38.2%) have years of experience between 5 and 10 years, 16 (23.5%) have years of experience between 10 and 15 years, and 13 (19.1%) have years of experience greater than 15 years. The outcomes of the respondent's year of work experience are presented in Table 4.3 below.

Table 4. 3: Professional work Experience

Professional work Experience	Frequency	Percent	Valid Percent	Cumulative Percent
Less than 5 years	13	19.1	19.1	19.1
5 - 10 years	26	38.2	38.2	57.4
11 - 15 years	16	23.5	23.5	80.9
Above 15 years	13	19.1	19.1	100.0
Total	68	100.0	100.0	

Source: Own survey data analysis

These findings show that more than 81% of respondents have more than five years of job experience. These results will also provide some assurance that the gathered data will reflect what it was intended for. Those respondents are in a good position inside their organizations to provide confidential and precise data. As a result, highly experienced respondents played critical roles in giving appropriate and relevant data that determined the research's sensible and logical outcome.

The study asked for and collected the respondents' professional positions as requested during the survey. 4 (5.9%) were architects, 12 (17.6%) were structural engineers, 3 (4.4%) were drafting aids, 7 (10.3%) were quantity surveyors, 8 (11.8%) were construction managers, 7 (10.3%) were site engineers, 4 (5.9%) were sanitary engineers, 3 (4.4%) were electrical engineers, 3 (4.4%) were mechanical engineers, 6 (8.8%) were safety engineers, 8 (11.8%) were surveyors and 3 (4.4%) were other professionals.

Table 4. 4: Professional position

Professional position	Frequency	Percent	Valid Percent	Cumulative Percent
Architect	4	5.9	5.9	5.9
Structural Engineer	12	17.6	17.6	23.5
Drafting aid	3	4.4	4.4	27.9
Quantity surveyor	7	10.3	10.3	38.2
Construction Manager	8	11.8	11.8	50.0
Site Engineer	7	10.3	10.3	60.3
Sanitary Engineer	4	5.9	5.9	66.2
Electrical Engineer	3	4.4	4.4	70.6
Mechanical Engineer	3	4.4	4.4	75.0
Safety Engineer	6	8.8	8.8	83.8
Surveyor	8	11.8	11.8	95.6
Others	3	4.4	4.4	100.0
Total	68	100.0	100.0	

Source: Own survey data analysis

The study sought to find out the education level of respondents and the responses were analyzed as shown in Table 4.5 below.

Table 4. 5: Educational background (qualification)

Educational background	Frequency	Percent	Valid Percent	Cumulative Percent

Below Diploma	8	11.8	11.8	11.8
Diploma	18	26.5	26.5	38.2
BSc / BA	28	41.2	41.2	79.4
MSC / MA	14	20.6	20.6	100.0
Total	68	100.0	100.0	

Source: Own survey data analysis

According to the study shown in Table 4.5, the respondents' highest educational level was a bachelor's degree or a diploma degree. The majority of respondents (41.2%) possess first degrees, followed by 26.5% who hold diploma degrees, 20.6% who hold master's degrees, and 11.8% who hold less than a diploma. This signified highly educated individuals with extensive skill and knowledge of the subject matter. This also aided the researcher in efficiently collecting data because the responders could read, write, and interpret the questions. As a result, highly educated respondents played an important role in supplying appropriate and relevant data, which determined the research outcome sensibly and logically.

Regarding the respondents' understanding of mass modular construction, 5 (7.4%) were familiar with the concept and had experience with mass modular construction, 32 (47.1%) were familiar with the concept but don't have experience with mass modular construction, 21 (30.9%) didn't have any concept about mass modular construction, 7 (10.3%) didn't have any concept but would like to know and work with mass modular construction, and 3 (4.4%) had none about mass modular construction. This indicates that the majority of respondents 32 (47.1%) were familiar with the concept but had no experience with mass modular building. Table 4.6 following provides more information on this.

Table 4. 6: Understanding of mass modular construction

Understanding of mass modular construction	Frequency	%	Valid %	Cumulative %
Familiar with the concept and had experience with it.	5	7.4	7.4	7.4
Familiar with the concept but don’t have experience with it.	32	47.1	47.1	54.4
Don’t have any concept	21	30.9	30.9	85.3

Don't have any concept but would like to know and work with it.	7	10.3	10.3	95.6
None	3	4.4	4.4	100.0
Total	68	100.0	100.0	

Source: Own survey data analysis

Based on the demographics of the respondents, the researcher determined that there is no significant difference between the different demographic groups when testing the factors analyzed. Furthermore, 61.8% of respondents have a first-degree or higher educational level; more than 81% have more than 5 years of job experience; and 47.1% are familiar with the concept but have no experience with mass modular building. As a result, respondents with an acceptable level of education, extensive work experience, and familiarity with the concept but no experience with mass modular building are more likely to provide adequate and relevant data, which improves the validity of the research results.

4.3. The key drivers of mass modular construction

Since respondents evaluated the primary drivers of mass modular building in linguistic terms, it was necessary to convert these linguistic assessments into numerical values using triangular fuzzy numbers. The linguistic phrases are translated into triangular fuzzy integers to create the fuzzy decision matrix for each choice. Thus, generate a fuzzy combined decision matrix that contains the identified major drivers of mass modular construction scores of each alternative with combined triangular fuzzy numbers, as shown in Appendix B.

The weighted normalized decision matrix, which normalizes the decision matrix to ensure that all criteria are on the same scale and then assigns weights to each of the key drivers of mass modular construction based on their relative importance, can be found in Appendix C. To calculate the fuzzy positive ideal solution (FPIS) and fuzzy negative ideal solution (FNIS) for each major driver of mass modular construction to reflect the best and worst performance levels, as illustrated in Table 4. 7.

Table 4. 7: FPIS and FNIS of the key drivers of mass modular construction

key drivers of mass modular construction	Normalized fuzzy decision matrix

Time efficiency	(0.111, 0.614, 1)
Waste reduction	(0.111, 0.667, 1)
Productivity performance	(0.111, 0.585, 1)
Quality performance	(0.111, 0.650, 1)
Safety performance	(0.111, 0.624, 1)
Cost performance	(0.111, 0.585, 1)
Social performance	(0.111, 0.598, 1)
Standardization	(0.111, 0.716, 1)
Weather	(0.111, 0.650, 1)
Good management	(0.111, 0.654, 1)
Land use optimization	(0.111, 0.716, 1)
Operation	(0.111, 0.689, 1)
A^+	(0.111, 0.781, 1)
A^-	(0.111, 0.585, 1)

Source: Own survey data analysis

Assess the fuzzy closeness coefficient by calculating the distance between each alternative and the FPIS and FNIS to assess their relative proximity to the ideal solution in descending order, as given in Table 4.8.

Table 4. 8: Closeness coefficient of the key drivers of mass modular construction

The key drivers of mass modular construction	d_i^+	d_i^-	CC_i	Rank
Land use optimization	0.040	0.078	0.684	1
Standardization	0.038	0.076	0.667	2
Operation	0.053	0.06	0.531	3
Waste reduction	0.066	0.047	0.416	4
Good management	0.073	0.039	0.348	5
Weather	0.077	0.037	0.325	6
Quality performance	0.078	0.036	0.316	7
Safety performance	0.091	0.023	0.202	8
Time efficiency	0.096	0.017	0.150	9

Social performance	0.106	0.008	0.07	10
Productivity performance	0.113	0.001	0.009	11
Cost performance	0.114	0.00	0.00	12

Source: Own survey data analysis

According to the study's findings, the top five key drivers of mass modular construction in Addis Abeba are land use optimization with a closeness coefficient value of 0.684, standardization with a closeness coefficient value of 0.667, operation with a closeness coefficient value of 0.531, waste reduction with a closeness coefficient value of 0.416 and good management with a closeness coefficient value of 0.348.

Land use optimization is crucial in Addis Ababa, where urbanization is accelerating. Mass modular construction makes efficient use of limited space by allowing for vertical construction and the development of multi-story buildings. This technique maximizes the capacity of available land, fulfilling the city's growing housing needs without expanding outward.

Standardization is critical in modular construction since it helps to streamline the building process. Standardized components and techniques make building more efficient, cost-effective, and error-free. In Addis Ababa, where housing and infrastructure are in high demand, standardization speeds up building while ensuring quality and consistency across projects.

Operation which is efficient operation of modular construction projects involves factors such as logistics, assembly, and maintenance. Modular construction allows for faster project completion due to simultaneous on-site and off-site work, reducing overall construction time. Additionally, modular buildings can be easily expanded or reconfigured, offering flexibility to adapt to changing needs over time. Effective operation ensures that modular construction projects in Addis Ababa are not only built quickly but also function optimally throughout their lifecycle.

Waste reduction which is traditional construction methods can produce significant waste, which contributes to environmental degradation and resource depletion. However, mass modular building reduces waste by using precise production methods and maximizing material consumption. Fabricating building components off-site in controlled manufacturing settings reduces extra material waste, resulting in a more sustainable construction method in Addis Ababa.

Good management which is effective project management is critical to the success of mass modular construction in Addis Ababa. This includes managing logistics, communicating with multiple parties, maintaining quality control, and adhering to deadlines and budgets. Good management methods help modular building projects run more efficiently and successfully, allowing them to satisfy the city's growing need for affordable and sustainable housing.

According to Bello et al. (2023), the study indicated that in general the time efficiency, waste reduction, productivity performance, quality performance, safety performance, cost performance, government, social performance, standardization, weather, good management, land use optimization, location and transportation, knowledge, operation efficiency and availability of adequate technology were identified as the most key drivers of mass modular construction. Therefore, the finding of this study is inline and complements with (Bello et al., 2023).

According to Joseph Yel Akok (2017), study indicated that the most key drivers of mass modular construction are time efficiency, waste reduction, productivity performance, quality performance, cost performance, standardization, weather and operation efficiency were identified. Therefore, once again this study finding is coincides with (Joseph Yel Akok, 2017).

According to Ismail et al. (2023), the study indicated that the most key drivers of mass modular construction are time efficiency, waste reduction, productivity performance, cost performance, social performance, weather, and location and transportation were identified. Therefore, once again this study finding is also coincides with (Ismail et al., 2023).

According to Khan et al. (2022), found that the major key drivers of mass modular construction are time efficiency, productivity performance, quality performance, cost performance, government and social performance were identified. Therefore, this study also more or less coincide with (Khan et al., 2022).

According to Makwana et al. (2017), on the other hand found the major key drivers of mass modular construction are time efficiency, waste reduction, productivity performance, quality performance, cost performance, government, weather, good management, location and transportation, operation efficiency and availability of adequate technology were identified. Therefore, this study also more or less coincide with (Makwana et al., 2017).

Finally, the most significant drivers of mass modular construction in Addis Ababa are land use optimization, standardization, efficient operation, waste reduction, and good management. These factors collectively contribute to addressing the city's housing needs in a sustainable, cost-effective, and timely manner, while also promoting urban development and environmental responsibility.

4.4. The challenges to the successful implementation of mass modular construction

Assessment of the challenges to the successful implementation of mass modular building for each selected major attribute. This study aims to examine the challenges to the successful implementation of mass modular construction in Addis Ababa. Because respondents rated the barriers to the effective implementation of mass modular building in linguistic terms, it was necessary to convert these linguistic judgments into numerical values using triangular fuzzy numbers. The linguistic phrases are translated into triangular fuzzy integers to create the fuzzy decision matrix for each choice.

Thus, generate a fuzzy combined choice matrix that contains the identified challenges to the effective implementation of mass modular construction scores of each alternative with combined triangular fuzzy numbers, as shown in Appendix D. The weighted normalized decision matrix, which normalizes the decision matrix to ensure that all criteria are on the same scale, and then assigns weights to each of the challenges to the successful implementation of mass modular construction based on their relative importance, can be found in Appendix E. To determine the fuzzy positive ideal solution (FPIS) and fuzzy negative ideal solution (FNIS) for each the challenges to the successful implementation of mass modular construction to represent the best and worst performance levels obtained as shown in Table 4. 9.

Table 4. 9: FPIS and FNIS of the challenges to the implementation of MMC

Challenges to the successful implementation of MMC	Normalized fuzzy decision matrix
Initial Investment Cost	(0.111, 0.523, 1)
Logistics and Transportation	(0.111, 0.601, 1)
Inadequate Coordination, Communication and Planning	(0.111, 0.585, 1)
Lack of awareness and knowledge	(0.111, 0.509, 1)

Site Processes	(0.111, 0.549, 1)
Lack of design Codes, Standards, Standardization and Supply Chain	(0.111, 0.572, 1)
Lack of Incentive and Government Support	(0.111, 0.611, 1)
Lack of qualified workers (experience and skills)	(0.111, 0.647, 1)
Limited market demand compared to conventional construction	(0.111, 0.624, 1)
Poor integration and interface performance with traditional method	(0.111, 0.631, 1)
Lack of government usage of modular construction	(0.111, 0.634, 1)
Lack of manufacturing capacity	(0.111, 0.611, 1)
Lack of regulatory framework for implementation and monitoring	(0.111, 0.679, 1)
Limited contractors with specialization in modular construction	(0.111, 0.650, 1)
Inadequate educational programs on structural and architectural aspects of modular construction	(0.111, 0.660, 1)
Lack of technology and testing institute/lab for modules	(0.111, 0.669, 1)
A^{+}	(0.111, 0.679, 1)
A^{-}	(0.111, 0.509, 1)

Source: Own survey data analysis

Assess the fuzzy closeness coefficient by calculating the distance between each alternative and the FPIS and FNIS to assess their relative proximity to the ideal solution in descending order, as given in Table 4.10.

Table 4. 10: Closeness coefficient of challenges to the implementation of MMC

Challenges to the successful implementation of MMC	d_i^{+}	d_i^{-}	CC_i	Rank
Lack of regulatory framework for implementation and monitoring	0.00	0.098	1.00	1
Lack of technology and testing institute/lab for modules	0.006	0.092	0.939	2
Inadequate educational programs on structural and architectural aspects of modular construction	0.011	0.087	0.888	3
Limited contractors with specialization in modular construction	0.017	0.081	0.827	4
Lack of qualified workers (experience and skills)	0.018	0.079	0.814	5
Lack of government usage of modular construction	0.026	0.072	0.735	6
Poor integration and interface performance with traditional method	0.028	0.070	0.714	7

Limited market demand compared to conventional construction	0.032	0.066	0.673	8
Lack of Incentive and Government Support	0.039	0.059	0.602	9
Lack of manufacturing capacity	0.039	0.059	0.602	9
Logistics and Transportation	0.045	0.053	0.541	11
Inadequate Coordination, Communication and Planning	0.054	0.044	0.449	12
Lack of design Codes, Standards, Standardization and Supply Chain	0.062	0.036	0.367	13
Site Processes	0.075	0.023	0.235	14
Initial Investment Cost	0.090	0.008	0.082	15
Lack of awareness and knowledge	0.098	0.000	0.000	16

Source: Own survey data analysis

The following points, in chronological sequence, illustrate the barriers to the successful implementation of mass modular construction in Addis Ababa, using the fuzzy TOPSIS technique described in Table 4.16 above. The top five most significant challenges to the successful implementation of mass modular construction in Addis Ababa are a lack of a regulatory framework for implementation and monitoring with closeness coefficient value 1.00, a lack of technology and a testing institute/lab for modules with closeness coefficient value 0.939, insufficient educational programs on structural and architectural aspects of modular construction with closeness coefficient value 0.888, a scarcity of contractors with modular construction specialization with closeness coefficient value 0.827 and a scarcity of qualified workers with closeness coefficient value 0.814.

Lack of regulatory framework for implementation and monitoring which is the absence of a comprehensive regulatory framework specific to mass modular construction poses a significant challenge. Without proper guidelines and regulations, there may be inconsistencies in quality control, safety standards, and compliance with building codes. Additionally, the lack of monitoring mechanisms can lead to potential issues in construction quality and adherence to design specifications.

The lack of a designated technology and testing center or laboratory for modular construction in Addis Ababa can impede the successful execution of large-scale modular construction projects.

Such an institute would be in charge of assessing the quality, durability, and safety of modular components to ensure that they fulfill the necessary criteria.

Inadequate educational programs on structural and architectural aspects of modular building, or the scarcity of educational programs that focus exclusively on the structural and architectural features of modular construction, can be a problem. This lack of specialized education may result in a shortage of experts with the essential knowledge and abilities to properly design and manage modular building projects.

Limited contractors with specialization in modular construction which is the scarcity of contractors with expertise in modular construction techniques can pose challenges in implementing mass modular construction projects. Modular construction requires specialized knowledge and experience, including understanding the design and assembly of modules, transportation logistics, and on-site installation. The limited number of contractors with this expertise can limit the scalability and timely execution of mass modular construction projects.

Lack of qualified workers (experience and skills) which is the shortage of qualified workers who are experienced and skilled in modular construction techniques is another significant challenge. Modular construction requires a different set of skills compared to traditional construction methods. The lack of trained workers can result in delays, errors, and reduced quality in the construction process.

According to Bello, Khan, et al. (2023), the study indicated that in general the initial investment cost; logistics and transportation; site processes; lack of design codes, standards, standardization and supply chain; lack of incentive and government support; lack of qualified workers (experience and skills); lack of government usage of modular construction; lack of manufacturing capacity; lack of regulatory framework for implementation and monitoring; limited contractors with specialization in modular construction; inadequate educational programs on structural and architectural aspects of modular construction; and lack of technology and testing institute/lab for modules were identified as the significant challenges to the successful implementation of mass modular construction. Therefore, the finding of this study is inline and complements with (Bello, Khan, et al., 2023).

According to Abdelmageed et al. (2020b), study indicated that the significant challenges to the successful implementation of mass modular construction are initial investment cost; logistics and transportation; Inadequate Coordination, Communication and Planning; Lack of awareness and knowledge; site processes; lack of design codes, standards, standardization and supply chain; and Lack of Incentive and Government Support were identified. Therefore, once again this study finding is coincides with (Abdelmageed et al., 2020b).

According to Kisi et al. (2019), the study indicated that the significant challenges to the successful implementation of mass modular construction are initial investment cost; logistics and transportation; inadequate coordination, communication and planning; lack of design codes, standards, standardization and supply chain; lack of incentive and government support; lack of qualified workers (experience and skills); limited market demand compared to conventional construction; poor integration and interface performance with traditional method; lack of manufacturing capacity; and lack of regulatory framework for implementation and monitoring were identified. Therefore, once again this study finding is also coincides with (Kisi et al., (2019).

According to Thurairajah et al. (2023) , found that the major challenges to the successful implementation of mass modular construction are initial investment cost; logistics and transportation; inadequate coordination, communication and planning; lack of design codes, standards, standardization and supply chain; and lack of qualified workers (experience and skills) were identified. Therefore, this study also more or less coincide with (Thurairajah et al., 2023).

According to Cantu et al. (2019), on the other hand found the major challenges to the successful implementation of mass modular construction are initial investment cost; logistics and transportation; inadequate coordination, communication and planning; site processes; lack of design codes, standards, standardization and supply chain; lack of qualified workers (experience and skills); lack of manufacturing capacity; and lack of regulatory framework for implementation and monitoring were identified. Therefore, this study also more or less coincide with (Cantu et al., (2019).

Thus, the results already show that the most significant challenges to the successful implementation of mass modular construction in Addis Ababa are a lack of a regulatory framework, the absence of a technology and testing institute for modules, insufficient educational programs on modular construction, a scarcity of contractors with modular construction specialization, and a shortage of skilled workers. To ensure the successful implementation of mass modular construction projects in Addis Ababa, appropriate regulations will need to be developed, testing facilities established, educational programs expanded, specialized contractor training promoted, and investment in workforce development initiatives increased.

4.5. The enabling strategies and best practices for implementing mass modular construction

The impact of each variable to overall enabling strategies and best practices was investigated, and the traits were ranked in terms of their perceived criticality by respondents using fuzzy TOPSIS techniques. Because respondents rated enabling methods and best practices for mass modular building using linguistic phrases, it was necessary to convert these language judgments into numerical values using triangular fuzzy numbers. The linguistic phrases are translated into triangular fuzzy integers to create the fuzzy decision matrix for each choice.

Thus, generate a fuzzy combined choice matrix that contains the identified enabling methods and best practices for implementing mass modular construction scores of each alternative with combined triangular fuzzy numbers, as shown in Appendix F. The weighted normalized decision matrix, which normalizes the decision matrix to ensure that all criteria are on the same scale, and then assigns weights to each of the enabling strategies and best practices for implementing mass modular construction based on their relative importance, is shown in Appendix G.

To determine the fuzzy positive ideal solution (FPIS) and fuzzy negative ideal solution (FNIS) for each the enabling strategies and best practices for implementing mass modular construction to represent the best and worst performance levels obtained as shown in Table 4. 11.

Table 4. 11: FPIS and FNIS of the enabling strategies for implementing MMC

The enabling strategies and best practices for implementing mass modular construction	Normalized fuzzy decision matrix
Increase of awareness among the professionals and stakeholders	(0.111, 0.771, 1)
Creating enabling environment within the industry	(0.111, 0.739, 1)

Government participating in the usage of modular construction	(0.111, 0.719, 1)
Institutions should be more rigorous in teaching modular construction	(0.111, 0.752, 1)
Encourage usage of new and improved technological tools such as Building Information Modeling (BIM), Internet of Things.	(0.111, 0.706, 1)
Professional bodies to trained members and encourage usage of modular construction	(0.111, 0.722, 1)
Establishing of policies and codes for modular construction	(0.111, 0.735, 1)
Establishing effective communication in the architecture engineering and construction industry	(0.111, 0.696, 1)
Good working collaboration, effective communication, and information sharing among modular integrated construction project participants	(0.111, 0.725, 1)
Improved supply chain coordination and management	(0.111, 0.676, 1)
Accurate design, early design freeze and timely owner's approval	(0.111, 0.601, 1)
Fully-integrated approach and involvement of key participants throughout the project	(0.111, 0.748, 1)
Extensive modular integrated construction project planning, scheduling and control	(0.111, 0.719, 1)
Adequate relevant experience and knowledge of contractor, designer, and manufacturer of modular integrated construction projects	(0.111, 0.709, 1)
Establishment and communication of a conflict resolution strategy	(0.111, 0.673, 1)
A willingness to share resources among project participants	(0.111, 0.752, 1)
A clear definition of responsibilities	(0.111, 0.667, 1)
A commitment to a win-win attitude	(0.111, 0.588, 1)
Regular monitoring of partnering process	(0.111, 0.729, 1)
A^{+}	(0.111, 0.771, 1)
A^{-}	(0.111, 0.588, 1)

Source: Own survey data analysis

From the above Table 4.11 result, determine the fuzzy closeness coefficient is calculate the distance between each alternative and the FPIS and FNIS to determine their relative closeness to the ideal solution obtained in descending order as shown in Table 4.12.

Table 4. 12: Closeness coefficient of enabling strategies for implementing MMC

The enabling strategies for implementing MMC	d_i^+	d_i^-	CC_i	Rank
Increase of awareness among the professionals and stakeholders	0.000	0.106	1.000	1
A willingness to share resources among project participants	0.011	0.095	0.896	2
Institutions should be more rigorous in teaching modular construction	0.012	0.094	0.887	3
Fully-integrated approach and involvement of key participants throughout the project	0.013	0.092	0.876	4
Creating enabling environment within the industry	0.018	0.087	0.829	5
Establishing of policies and codes for modular construction	0.021	0.085	0.802	6
Regular monitoring of partnering process	0.024	0.081	0.771	7
Good working collaboration, effective communication, and information sharing among modular integrated construction project participants	0.027	0.079	0.745	8
Professional bodies to trained members and encourage usage of modular construction	0.028	0.077	0.733	9
Extensive modular integrated construction project planning, scheduling and control	0.030	0.076	0.717	10
Government participating in the usage of modular construction	0.030	0.076	0.717	10
Adequate relevant experience and knowledge of contractor, designer, and manufacturer of modular integrated construction projects	0.036	0.070	0.660	12
Encourage usage of new and improved technological tools such as Building Information Modeling (BIM), Internet of Things.	0.038	0.068	0.642	13
Establishing effective communication in the architecture engineering and construction industry	0.043	0.062	0.590	14
Improved supply chain coordination and management	0.055	0.051	0.481	16
Establishment and communication of a conflict resolution strategy	0.057	0.049	0.462	17
A clear definition of responsibilities	0.060	0.046	0.434	19
Accurate design, early design freeze and timely owner’s approval	0.098	0.008	0.075	20

A commitment to a win-win attitude	0.106	0.000	0.000	21

Source: Own survey data analysis

As the results of the study shown above, it clearly indicates that the dominant top five relatively most effective enabling strategies and best practices for implementing mass modular construction in Addis Ababa are increase of awareness among the professionals and stakeholders, a willingness to share resources among project participants, institutions should be more rigorous in teaching modular construction, fully-integrated approach and involvement of key participants throughout the project and creating enabling environment within the industry.

Increase of awareness among the professionals and stakeholders which is raising awareness about the benefits and potential of mass modular construction among architects, engineers, contractors, and other stakeholders is crucial. This can be achieved through workshops, seminars, and training programs that highlight the advantages of modular construction, as well as its potential to address housing shortages and infrastructure needs in Addis Ababa.

Willingness to share resources among project participants which is encouraging collaboration and resource-sharing among project participants, including developers, contractors, and manufacturers, can enhance the efficiency and cost-effectiveness of mass modular construction projects. This may involve establishing partnerships and networks to facilitate the exchange of knowledge, expertise, and resources.

Institutions should be more rigorous in teaching modular construction which is educational institutions should integrate modular construction principles and practices into their curricula to ensure that future professionals are well-equipped with the necessary knowledge and skills. By incorporating modular construction into academic programs, students can be better prepared to contribute to the successful implementation of modular construction projects in Addis Ababa.

Fully-integrated approach and involvement of key participants throughout the project which is adopting a fully-integrated approach that involves key participants, such as designers, manufacturers, contractors, and regulatory authorities, from the early stages of a project can lead to better coordination, communication, and decision-making. This approach can help address potential challenges and ensure that all aspects of the project are considered holistically.

Creating an enabling environment within the industry which is fostering an enabling environment within the construction industry involves establishing supportive policies, incentives, and regulations that promote the adoption of mass modular construction. This may include streamlining approval processes for modular projects, providing financial incentives for adopting innovative construction methods, and creating standards and guidelines specific to modular construction.

According to Esmaeili et al. (2016), the study indicated that in general the Establishment and communication of a conflict resolution strategy; willingness to share resources among project participants; clear definition of responsibilities; commitment to a win-win attitude; and Regular monitoring of partnering process were identified as the significant enabling strategies and best practices for implementing mass modular construction. Therefore, the finding of this study is inline and complements with (Esmaeili et al., 2016).

According to Bello, Ihedigbo, et al. (2023)(Abdelmageed et al., 2020b), study indicated that the significant enabling strategies and best practices for implementing mass modular construction are increase of awareness among the professionals and stakeholders; creating enabling environment within the industry; government participating in the usage of modular construction; adequate transportation system to transport large modules; institutions should be more rigorous in teaching modular construction; encourage usage of new and improved technological tools such as building information modeling (BIM), internet of things (IOT); professional bodies to trained members and encourage usage of modular construction; establishing of policies and codes for modular construction; establishing effective communication in the architecture engineering and construction industry; good working collaboration, effective communication, and information sharing among modular construction project participants; accurate design, early design freeze and timely owner’s approval; extensive modular integrated construction project planning, scheduling and control; and adequate relevant experience and knowledge of contractor, designer, and manufacturer of modular integrated construction projects were identified. Therefore, once again this study finding is coincides with (Bello, Ihedigbo, et al., 2023).

According to (Wuni & Shen (2020), the study indicated that the significant enabling strategies and best practices for implementing mass modular construction are increase of awareness among the professionals and stakeholders; government participating in the usage of modular construction; adequate transportation system to transport large modules; professional bodies to trained members and encourage usage of modular construction; establishing of policies and codes for modular construction; establishing effective communication in the architecture engineering and construction industry; good working collaboration, effective communication, and information sharing among modular construction project participants; improved supply chain coordination and management; accurate design, early design freeze and timely owner's approval; fully-integrated approach and involvement of key participants throughout the project; standardization, optimization, and benchmarking of best practices; extensive modular integrated construction project planning, scheduling and control; adequate relevant experience and knowledge of contractor, designer, and manufacturer of modular integrated construction projects; willingness to share resources among project participants; and regular monitoring of partnering process were identified. Therefore, once again this study finding is also coincides with (Wuni & Shen, 2020).

According to Lafhaj et al. (2016), found that the major enabling strategies and best practices for implementing mass modular construction are professional bodies to trained members and encourage usage of modular construction; establishing of policies and codes for modular construction; accurate design, early design freeze and timely owner's approval; and fully-integrated approach and involvement of key participants throughout the project were identified. Therefore, this study also more or less coincide with (Lafhaj et al., (2016).

All in all, the most effective enabling strategies and best practices for implementing mass modular construction in Addis Ababa include increasing awareness among professionals and stakeholders, promoting resource-sharing, enhancing education on modular construction, adopting a fully-integrated approach, and creating an enabling environment within the industry. By implementing these strategies, Addis Ababa can overcome barriers to mass modular construction and pave the way for sustainable and efficient urban development.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

In this chapter major findings of this study were addressed and recommendations for procuring entities and future research were drawn.

5.1.Conclusion

The overall objective of this research was to investigate the drivers, challenges, and enabling strategies that influence the successful implementation of mass modular construction in Ethiopia, specifically in Addis Ababa. The specific objectives included to analyzing the key drivers of mass modular construction, to investigating the challenges and to investigating the enabling strategies and best practices for implementing mass modular construction in Ethiopia. With this in mind, the conclusion specifically presents the major findings obtained based on the data analyzed. Therefore, the researcher has drawn the conclusion as follows:

The key drivers of mass modular construction in Addis Ababa include the land use optimization, standardization, efficient operation, waste reduction, and good management. These factors collectively contribute to addressing the city's housing needs in a sustainable, cost-effective, and timely manner, while also promoting urban development and environmental responsibility. By leveraging these drivers effectively, stakeholders in the construction industry can capitalize on the benefits of modular construction to address the city's growing housing needs, optimize land use, improve construction efficiency, and enhance overall project outcomes.

The most significant challenges to the successful implementation of mass modular construction in Addis Ababa include the lack of a regulatory framework, absence of a technology and testing institute for modules, inadequate educational programs on modular construction, limited contractors with specialization in modular construction, and a shortage of qualified workers. Addressing these challenges will require the development of appropriate regulations, establishment of testing facilities, expansion of educational programs, promotion of specialized contractor training, and investment in workforce development initiatives to ensure the successful implementation of mass modular construction projects in Addis Ababa.

The most effective enabling strategies and best practices for implementing mass modular construction in Addis Ababa include increasing awareness among professionals and stakeholders, promoting resource-sharing, enhancing education on modular construction, adopting a fully-integrated approach, and creating an enabling environment within the industry. By implementing these strategies, Addis Ababa can overcome barriers to mass modular construction and pave the way for sustainable and efficient urban development.

5.2.Recommendations

After considering the aforementioned findings and conclusions, it is possible to move forward with the following suggestions and recommendations for effectively to the successful implementation and sustainability of mass modular construction in Addis Ababa.

Recommendation for government and regulatory authorities:

- Increase Awareness: Educate policymakers and regulatory authorities about the benefits of mass modular construction and its potential to address housing shortages and infrastructure challenges.
- Create Supportive Policies: Develop regulations that support and encourage modular construction, including streamlined permitting processes and incentives for developers.
- Invest in Infrastructure: Allocate resources for the development of modular construction facilities and training programs to support the growth of the industry.

Recommendation for developers and investors:

- Collaborate with Stakeholders: Engage with designers, manufacturers, and contractors early in the project planning phase to optimize design and ensure project success.
- Invest in Training: Provide training programs for staff to build expertise in modular construction techniques and processes.
- Explore Financing Options: Investigate funding opportunities and financial incentives for modular construction projects to reduce costs and attract investment.

Recommendation for designers and architects:

- Enhance Education: Incorporate modular construction principles into design curricula and training programs to equip professionals with the necessary skills.
- Collaborate with Manufacturers: Work closely with modular construction companies to develop innovative designs that maximize the benefits of modular construction.

- Stay Informed: Keep abreast of industry trends, technologies, and best practices to ensure designs are optimized for modular construction methods.

Recommendation for manufacturers and suppliers:

- Innovate and Adapt: Invest in research and development to improve modular construction techniques and develop new products that meet the specific needs of the Addis Ababa market.
- Build Partnerships: Collaborate with developers, designers, and contractors to streamline processes and enhance the efficiency of modular construction projects.

Recommendation for contractors and builders:

- Training Programs: Provide training for construction teams on modular construction methods and best practices to ensure successful project implementation.
- Embrace Technology: Adopt digital tools and construction technologies that enhance efficiency and productivity in modular construction projects.
- Compliance with Regulations: Ensure that all construction activities comply with building codes and regulations specific to modular construction to avoid delays or setbacks.

By tailoring these recommendations to the specific needs and roles of different stakeholders involved in mass modular construction projects in Addis Ababa, each group can contribute effectively to the successful implementation and sustainability of modular construction in the city.

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Appendix

Appendix A: Survey Questionnaire

Adama Science and Technology University

School of Civil Engineering and Architecture

Department of Civil Engineering

Questionnaire survey for thesis paper on the A successful implementation mass modular construction in Ethiopia: in a case study of Addis Ababa.

Dear/Sir;

The purpose of this questionnaire is to collect data for the research study entitled **"A successful implementation mass modular construction in Ethiopia: in a case study of Addis Ababa"** as a fulfillment of the requirement for the Degree of Master of Science in department of Civil Engineering. Thus, your genuine, professional opinion and timely responses are vital to determine the success of this study. Please note that the information you provide will only be used for academic purpose and all the information revealed will be kept confidential. To this end, you are kindly requested to contribute your own share by filling in the questionnaires honestly and responsibly for further recommendations to improve similar works in the future. Thank you in advance for your cooperation!!!

If you need further explanation, you can contact me through the address indicated below:

Negese Dabi Tola, Mobile Number: +2519-13-617308 or +2519-10-574993

Email: negasadabi2022@gmail.com

General Instruction:

- No need of writing your name/address.
- To those questions with alternatives mark your response on the space provided by putting " ✓ "
- For any additional option or explanation you are kindly requested to write briefly on the space provided.

<u>Part One:</u> - General information about the respondents

1. What is your official occupational title at your institution?
   a. Director of Housing
   b. Director of Design and Construction
   c. Director of Physical Plant
   d. Other (please specify) ____________
2. Years of professional work Experience? (estimate)
   a. Less than 5 years   b. 6 - 10 years   c. 11 - 15 years   d. above 15 years
3. What is your professional position?
   a. Construction Manager   f. Safety Engineer   k. Surveyor
   b. Architect   g. Site Engineer   l. Other _________
   c. Structural Engineer   h. Sanitary Engineer
   d. Drafting aid   i. Electrical Engineer
   e. Quantity surveyor   j. Mechanical Engineer
4. Educational background:
   a. Below Diploma   b. Diploma   c. BSc/BA   d. MSc/MA   e. PhD & above
5. What is your understanding of mass modular construction?
   a. I am familiar with the concept and I had experience with it.
   b. I am familiar with the concept but I don't have experience with it.
   c. I don't have any concept.
   d. I don't have any concept but I would like to know and work with it.
   e. None.

Part Two: - The Mass Modular Construction in Addis Ababa

1. To what extent are you agreeing with the key drivers of mass modular construction in Ethiopian? Please indicate the most important drivers by making on the appropriate box using the following a 5-point Likert importance weighting scale:

Linguistic scales	**Symbol**	**Number**	**Fuzzy Number**
Not Important	NI	1	(1, 1, 3)
Slightly Important	SI	2	(1, 3, 5)
Moderately Important	MI	3	(3, 5, 7)
Important	I	4	(5, 7, 9)
Extremely Important	EI	5	(7, 9, 9)

Code	The key drivers of mass modular construction in Addis Ababa	Importance weighting				
		NI	SI	MI	I	EI
1.1	Time efficiency					
1.2	Waste reduction					
1.3	Productivity performance					
1.4	Quality performance					
1.5	Safety performance					
1.6	Cost performance					
1.7	Social performance					
1.8	Standardization					
1.9	Weather					
1.10	Good management					
1.11	Land use optimization					
1.12	Operation					

2. To what extent are you agreeing with the challenges to the successful implementation of mass modular construction in Ethiopia? Please indicate the highest challenges by making on the appropriate box using the following a 5-point Likert importance weighting scale:

Linguistic scales	Symbol	Number	Fuzzy Number
Very Low Challenge	VLC	1	(1, 1, 3)
Low Challenge	LC	2	(1, 3, 5)
Moderately Challenge	MC	3	(3, 5, 7)
High Challenge	HC	4	(5, 7, 9)
Very High Challenge	VHC	5	(7, 9, 9)

Code	The challenges to the successful implementation of mass modular construction	Importance weighting				
		1	2	3	4	5
2.1	Initial Investment Cost					
2.2	Logistics and Transportation					
2.3	Inadequate Coordination, Communication and Planning					
2.4	Lack of awareness and knowledge					
2.5	Site Processes					
2.6	Lack of design Codes, Standards, Standardization and Supply Chain					
2.7	Lack of Incentive and Government Support					
2.8	Lack of qualified workers (experience and skills)					
2.9	Limited market demand compared to conventional construction					
2.10	Poor integration and interface performance with traditional method					

2.11	Lack of government usage of modular construction					
2.12	Lack of manufacturing capacity					
2.13	Lack of regulatory framework for implementation and monitoring					
2.14	Limited contractors with specialization in modular construction					
2.15	Inadequate educational programs on structural and architectural aspects of modular construction					
2.16	Lack of technology and testing institute/lab for modules					

3. To what extent are you agree with the enabling strategies and best practices for implementing mass modular construction in Ethiopia? Please indicate the most effective enabling strategies and best practices by making on the appropriate box using the following a 5-point Likert importance weighting scale:

Linguistic scales	**Symbol**	**Number**	**Fuzzy Number**
Not Effective	NE	1	(1, 1, 3)
Slightly Effective	SE	2	(1, 3, 5)
Moderately Effective	ME	3	(3, 5, 7)
Effective	E	4	(5, 7, 9)
Extremely Effective	EE	5	(7, 9, 9)

Code	**The enabling strategies and best practices for implementing mass modular construction**	Importance weighting				
		1	**2**	**3**	**4**	**5**
3.1	Increase of awareness among the professionals and stakeholders					
3.2	Creating enabling environment within the industry					
3.3	Government participating in the usage of modular construction					
3.4	Institutions should be more rigorous in teaching modular construction					
3.5	Encourage usage of new and improved technological tools such as Building Information Modeling (BIM), Internet of Things.					
3.6	Professional bodies to trained members and encourage usage of modular construction					
3.7	Establishing of policies and codes for modular construction					
3.8	Establishing effective communication in the architecture engineering and construction industry					
3.9	Good working collaboration, effective communication, and information sharing among modular integrated construction project participants					
3.10	Improved supply chain coordination and management					
3.11	Accurate design, early design freeze and timely owner's approval					

3.12	Fully-integrated approach and involvement of key participants throughout the project					
3.13	Extensive modular integrated construction project planning, scheduling and control					
3.14	Adequate relevant experience and knowledge of contractor, designer, and manufacturer of modular integrated construction projects					
3.15	Establishment and communication of a conflict resolution strategy					
3.16	A willingness to share resources among project participants					
3.17	A clear definition of responsibilities					
3.18	A commitment to a win-win attitude					
3.19	Regular monitoring of partnering process					

Appendix B: Combined triangular fuzzy numbers for key drivers of MMC

key drivers of mass modular construction	Combined triangular fuzzy numbers
Time efficiency	(1, 5.529, 9)
Waste reduction	(1, 6, 9)
Productivity performance	(1, 5.265, 9)
Quality performance	(1, 5.853, 9)
Safety performance	(1, 5.618, 9)
Cost performance	(1, 5.265, 9)
Social performance	(1, 5.382, 9)
Standardization	(1, 6.441, 9)
Weather	(1, 5.853, 9)
Good management	(1, 5.882, 9)
Land use optimization	(1, 6.441, 9)
Operation	(1, 6.206, 9)

Appendix C: Weighted normalized fuzzy decision matrix for the key drivers

key drivers of mass modular construction	Normalized fuzzy decision matrix
Time efficiency	(0.111, 0.614, 1)
Waste reduction	(0.111, 0.667, 1)
Productivity performance	(0.111, 0.585, 1)
Quality performance	(0.111, 0.650, 1)
Safety performance	(0.111, 0.624, 1)
Cost performance	(0.111, 0.585, 1)
Social performance	(0.111, 0.598, 1)
Standardization	(0.111, 0.716, 1)
Weather	(0.111, 0.650, 1)
Good management	(0.111, 0.654, 1)
Land use optimization	(0.111, 0.716, 1)
Operation	(0.111, 0.689, 1)

Appendix D: Combined triangular fuzzy numbers for Challenges

challenges to the successful implementation of MMC	Combined triangular fuzzy numbers
Initial Investment Cost	(1, 4.706, 9)
Logistics and Transportation	(1, 5.412, 9)
Inadequate Coordination, Communication and Planning	(1, 5.265, 9)
Lack of awareness and knowledge	(1, 4.588, 9)
Site Processes	(1, 4.941, 9)
Lack of design Codes, Standards, Standardization and Supply Chain	(1, 5.147, 9)
Lack of Incentive and Government Support	(1, 5.50, 9)
Lack of qualified workers (experience and skills)	(1, 5.824, 9)
Limited market demand compared to conventional construction	(1, 5.618, 9)
Poor integration and interface performance with traditional method	(1, 5.677, 9)
Lack of government usage of modular construction	(1, 5.706, 9)
Lack of manufacturing capacity	(1, 5.50, 9)
Lack of regulatory framework for implementation and monitoring	(1, 6.118, 9)
Limited contractors with specialization in modular construction	(1, 5.853, 9)
Inadequate educational programs on structural and architectural aspects of modular construction	(1, 5.941, 9)
Lack of technology and testing institute/lab for modules	(1, 6.029, 9)

Appendix E: Weighted normalized fuzzy decision matrix for Challenges

Challenges to the successful implementation of MMC	Normalized fuzzy decision matrix
Initial Investment Cost	(0.111, 0.523, 1)
Logistics and Transportation	(0.111, 0.601, 1)
Inadequate Coordination, Communication and Planning	(0.111, 0.585, 1)
Lack of awareness and knowledge	(0.111, 0.509, 1)
Site Processes	(0.111, 0.549, 1)
Lack of design Codes, Standards, Standardization and Supply Chain	(0.111, 0.572, 1)
Lack of Incentive and Government Support	(0.111, 0.611, 1)
Lack of qualified workers (experience and skills)	(0.111, 0.647, 1)
Limited market demand compared to conventional construction	(0.111, 0.624, 1)
Poor integration and interface performance with traditional method	(0.111, 0.631, 1)
Lack of government usage of modular construction	(0.111, 0.634, 1)
Lack of manufacturing capacity	(0.111, 0.611, 1)
Lack of regulatory framework for implementation and monitoring	(0.111, 0.679, 1)
Limited contractors with specialization in modular construction	(0.111, 0.65, 1)
Inadequate educational programs on structural and architectural aspects of modular construction	(0.111, 0.66, 1)
Lack of technology and testing institute/lab for modules	(0.111, 0.669, 1)

Appendix F: Combined triangular fuzzy numbers for the enabling strategies

The enabling strategies and best practices for implementing mass modular construction	Combined triangular fuzzy numbers
Increase of awareness among the professionals and stakeholders	(1, 6.941, 9)
Creating enabling environment within the industry	(1, 6.647, 9)
Government participating in the usage of modular construction	(1, 6.471, 9)
Institutions should be more rigorous in teaching modular construction	(1, 6.765, 9)
Encourage usage of new and improved technological tools such as Building Information Modeling (BIM), Internet of Things.	(1, 6.353, 9)
Professional bodies to trained members and encourage usage of modular construction	(1, 6.50, 9)
Establishing of policies and codes for modular construction	(1, 6.618, 9)
Establishing effective communication in the architecture engineering and construction industry	(1, 6.265, 9)
Good working collaboration, effective communication, and information sharing among modular integrated construction project participants	(1, 6.529, 9)
Improved supply chain coordination and management	(1, 6.088, 9)
Accurate design, early design freeze and timely owner's approval	(1, 5.412, 9)
Fully-integrated approach and involvement of key participants throughout the project	(1, 6.735, 9)
Extensive modular integrated construction project planning, scheduling and control	(1, 6.471, 9)
Adequate relevant experience and knowledge of contractor, designer, and manufacturer of modular integrated construction projects	(1, 6.382, 9)
Establishment and communication of a conflict resolution strategy	(1, 6.059, 9)
A willingness to share resources among project participants	(1, 6.765, 9)
A clear definition of responsibilities	(1, 6.00, 9)
A commitment to a win-win attitude	(1, 5.294, 9)
Regular monitoring of partnering process	(1, 6.559, 9)

Appendix G: Weighted normalized fuzzy decision matrix for the enabling strategies

The enabling strategies and best practices for implementing mass modular construction	Normalized fuzzy decision matrix
Increase of awareness among the professionals and stakeholders	(0.111, 0.771, 1)
Creating enabling environment within the industry	(0.111, 0.739, 1)
Government participating in the usage of modular construction	(0.111, 0.719, 1)
Institutions should be more rigorous in teaching modular construction	(0.111, 0.752, 1)
Encourage usage of new and improved technological tools such as Building Information Modeling (BIM), Internet of Things.	(0.111, 0.706, 1)
Professional bodies to trained members and encourage usage of modular construction	(0.111, 0.722, 1)
Establishing of policies and codes for modular construction	(0.111, 0.735, 1)
Establishing effective communication in the architecture engineering and construction industry	(0.111, 0.696, 1)
Good working collaboration, effective communication, and information sharing among modular integrated construction project participants	(0.111, 0.725, 1)
Improved supply chain coordination and management	(0.111, 0.676, 1)
Accurate design, early design freeze and timely owner's approval	(0.111, 0.601, 1)
Fully-integrated approach and involvement of key participants throughout the project	(0.111, 0.748, 1)
Extensive modular integrated construction project planning, scheduling and control	(0.111, 0.719, 1)
Adequate relevant experience and knowledge of contractor, designer, and manufacturer of modular integrated construction projects	(0.111, 0.709, 1)
Establishment and communication of a conflict resolution strategy	(0.111, 0.673, 1)
A willingness to share resources among project participants	(0.111, 0.752, 1)
A clear definition of responsibilities	(0.111, 0.667, 1)
A commitment to a win-win attitude	(0.111, 0.588, 1)
Regular monitoring of partnering process	(0.111, 0.729, 1)