ADDIS ABABA UNIVERSITY

COLLEGE OF TECHNOLOGY AND BUILT ENVIRONMENT

SCHOOL OF BUILT ENVIRONMENT

MANAGING THE HOUSING SUPPLY PROCESS'S FAILURE IN ETHIOPIA'S URBAN TRANSITION PROCESS: THE 3D CONSTRUCTION PRINTING TECNOLOGY ENABLING GAP IN ADDIS ABABA

By

Melat Teklegiorgis Hailu

June, 2025

Addis Ababa, Ethiopia

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A thesis submitted to the school of graduate studies of Addis Ababa University, college of technology and built environment for school of built environment in partial fulfillment for master's degree in Housing and Sustainable Development

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Declaration

I declare that the research entitled as “MANAGING THE HOUSING SUPPLY PROCESS’S FAILURE IN ETHIOPA’S URBAN TRANSITION PROCESS: THE 3D CONSTRUCTION PRINTING TECNOLOGY ENABLING GAP IN ADDIS ABABA” is my own original work that is not presented anywhere for a degree award and all the sources of material in this thesis have been acknowledged appropriately.

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This is to certify that the research entitled “MANAGING THE HOUSING SUPPLY PROCESS’S FAILURE IN ETHIOPA’S URBAN TRANSITION PROCESS: THE 3D CONSTRUCTION PRINTING TECNOLOGY ENABLING GAP IN ADDIS ABABA” is submitted for examination with my approval as institute advisor.

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List of Acronyms

3D printing- Three dimensional printing

AAHDMB - Addis Ababa Housing Development and Management Bureau

COBOD - Construction of Buildings on Demand

ECDSWC - Ethiopian Construction Design & Supervision Works Corporation

ESS – Ethiopian Statistical Service

ETB - Ethiopian Birr

IHDP - Integrated Housing Development Program

MOUDH - Ministry of Urban Development and Housing

NGO- Non-governmental organization

UAE- United Arab Emirates

UN - United Nations

UNCHS - United Nations Centre for Human Settlements

UNDP - United Nations Development Program

UN-HABITAT - United Nations Human Settlements Program

General Notes

All years are in Gregorian calendar unless specified

All money is in Ethiopian birr: 1 USD= 135.02.10 ETB, as of June13 2025.

ABSTRACT

Addis Ababa, as the political and economic heart of Ethiopia, is undergoing a rapid urban transition characterized by increasing rural-to-urban migration and growing demand for housing. However, the city continues to face a critical failure in managing its housing supply process one largely attributed to a significant technology gap in the planning, execution, and governance mechanisms.This research is aimed at investigation of the construction technologies used in the housing supply system in Ethiopia and the extent to which the 3D construction printing technology is enabled to reduce the systems gaps. Urban housing supply failure is a global phenomenon which has affected close to 1billion people across the world. One of the instruments by which efforts are made to manage the failure is the application of improved construction technologies such as the robotic 3D construction printing technologies that use 3D printing as a core method to fabricate buildings or construction components. The literature indicates that the technology has the advantage of reducing construction cost and time and increasing design flexibility. Based on current growth rate the Ethiopian population is expected to double in the next 30 years and cross 210 million by 2060 indicating that the country will be in an ever more increasing pressure in the supply of affordable housing and in improving housing construction technologies. A case study approach of interview, extensive document review, and study of the existing construction technologies is done. In addition, review of the literature in order to investigate the preconditions for the transfer of the 3D construction printing technology is conducted.

Key Words: **3D construction, Construction technology, Housing supply, Urban Housing**

CHAPTER ONE

INTRODUCTION

According to the “World Urban Forum III”; ‘The world is facing a global housing crisis. In cities around the world, almost 1 billion people live in substandard housing without clean water or adequate sanitation. The international response to the housing crisis has been muted. While many international donors have helped develop effective models for housing policies and programs, the scale of their application has not been large enough to significantly affect housing outcomes. Many international institutions have turned away from the housing sector over the past 15 years. To overcome the housing problem countries have been developed and follows innovative housing technology programs to bring lending opportunities to those who do not currently have them through housing loans, with terms affordable to those with modest incomes.

1.1 Background of the Study

The stagnant nature of economic development and rapid population growth of most of the developing countries makes effective and efficient service delivery difficult for governments, to satisfy the need of their residents. Housing is one of the basic necessities for human survival; despite it remains for long period as a critical problem of most of the cities of developing countries. Developing countries, including Ethiopia, have limited access to alternative building materials and innovative construction techniques. Furthermore, the price of accessible Materials is costly, accounting for around 70% of total building costs.

There was a shortage of housing as a result of the population growth, particularly for those in the low- and middle-income groups. These difficulties in providing everyone with an inexpensive place to live Based on the current rate of growth (3.02%), the population of Ethiopia is expected to double in the next 30 years and cross 210 million by 2060 implying a higher demand in housing need Lack of sufficient and affordable housing is one of the major problems in Addis Ababa as

well as in other cities and towns across the country. Even though there is an increase in the supply of housing for lower and middle-income city dweller by the government agencies there is still a huge gap between housing needs and supply in Addis Ababa.

Housing affordability and provision of an adequate shelter are the challenges faced by the City Administration of Addis Ababa. When the phenomenal rise in population, it resulted in shortage of dwelling units of housing especially for the low and middle income group earner.

In 2004E.C. Ethiopian government has introduced a new housing policy and strategy called 10/90, 20/80, 40/60, and cooperative developments, with a primary focus on the capital city. The success of the program relies on the applicants' ability to save money. The local government has managed to register nearly 800,000 residents for the 20/80 and 40/60 programs alone. Yet it has not still managed to cover all the register applicants. The reason could be due to the long time frame it takes to construct or the cost of the day to day increasing materials. Affordably priced housing technology is essential to boosting house ownership and may lower building construction costs.

This aspect further motivated me to pursue newly and fast technological construction that our country is practicing this field. Adding to that the study reviews the affordable housing technologies used in Addis Ababa, Ethiopia to provide affordable housing system. The potential of technology to provide an affordable housing system is identified and described.

As the study on the area depicted there were technologies, which can contribute to housing which are Concrete hollow blocks, Aluminum Formwork, Pre-fabricated Housing, Concrete and Qacha Housing Technology, Mud Block (Adobe blocks) and 3D Housing Technology.

1.2 Statement of the Problem

Ethiopia, like many developing countries, is experiencing a significant influx of people migrating from rural areas to urban centers in search of better opportunities.

This demographic shift has put immense pressure on the housing sector, leading to a shortage of adequate and affordable housing options. The existing housing supply process is exacerbated by high construction costs, long project timelines, and inconsistent quality of housing units.

Conferring to Article 90 of Ethiopia's constitution from 1994, "Policies shall aim to guarantee all Ethiopians access to public health and education, clean-water, housing, food, and social security to the degree the country's resources permit." Owning a home is a goal that is still far off due to the city of Addis's escalating housing shortage and the rapid growth of informal settlements. The government is making significant efforts to ease the housing crisis in cities. There have already been noticeable results. However, it is necessary to plan and implement an alternative housing development that encourages individual private home builders, real estate development, housing cooperatives, and participation from various government institutions in order to gradually solve the housing problem in order to provide enough houses at a fair price to all segments of society becoming a mandatory.

The failure to address these challenges has significant implications for sustainable urban development and social equity. Without a well-managed housing supply process, many residents in Ethiopia's urban areas, particularly in Addis Ababa are forced to live in informal settlements with poor living conditions and limited access to essential services.

Effective management of the housing supply process requires a holistic approach that incorporates innovative technologies, streamlined regulatory frameworks, and strategic partnerships between the public and private sectors. By addressing these underlying issues, Ethiopia can enhance its urban transition process and ensure adequate housing for all its residents.

The research therefore seeks to address these challenges by identifying the shortcomings in the current housing supply process, evaluating alternative construction technologies, and providing recommendations on how to close the performance gap in housing development through 3D technological innovations, the

goal is to enhance the housing supply process in Addis Ababa and provide affordable and quality housing for its residents.

1.3 Objective of the Study

This study examines how alternative technologies for constructing housing are employed in Addis Ababa. The research is conducted in context of a thematic research project which has the following three objectives

- To investigate the practice of managing the housing supply process's failure by using construction technology in Addis Ababa
- To recommend how the management gap can be minimized
- To consider possibilities as regards introducing of new sustainable housing technology, in an urban context in Addis Ababa.

1.3.1 Specific objective

- To investigate the housing supply process and management system performance in Addis Ababa
- To investigate the performance gaps of alternative technologies
- To recommend how the gaps can be managed considering house construction technology

1.4 Research questions

1. What are the gaps of the housing supply process's failure Management systems by using constriction technologies in Addis Ababa?
2. How can the gaps be minimized?
3. What are the performance indicators of each technology in terms of time, cost and quality?

1.5 Scope of the study

The research primarily centers on Apartments and G+0 houses built by the Six (6) alternative house technologies Aluminum form work, Pre-fabricated technologies,

concrete and qacha construction Technologies, Mud blocks construction technologies and 3D Printing technology which have been chosen as the subject of the case study. The study focuses in Addis Ababa, Ethiopia in terms of development, unit management, and resident affordability. These Six (6) technologies were selected to examine and understand the construction technology development process of building units and draw lessons for the future and to evaluate the management of these units, including identifying the gap which hinders the progress of the technology and its impact on the supply process to the needy resident.

1.6 Significance of the Study

The inadequate housing supply can have significant socio-economic impacts on the residents of Addis Ababa. Understanding the reasons behind the technology gap in managing housing supply can help in addressing issues related to affordability, accessibility, and quality of housing in urban areas. By identifying the gaps in the management system, policymakers can develop more robust and sustainable solutions for managing urban housing supply. Further, Addis Ababa, as the capital city of Ethiopia, plays a crucial role in the country's urban transition process. Studying the technology gap in the housing supply management system can provide insights into the city's development planning and infrastructure requirements.

1.7 Limitation of the Study

As studies on Alternative building house technology system in reliance to affordable residential houses are limited the availability of data in the study area is one of the challenges. In line with this taking photograph for data collection, organizing the data about housing technology fabrication and producing the research is the other limitation for the researcher. To overcome this photographs and related documents from other researches is taken as a fulfillment.

1.8 Organization of the Study

This study is organized into six chapters. The first chapter proved a general background to the study, problem statement, study objectives and research question, scope of the study and limitation. The second chapter gives review of the relevant literature for the study while the third chapter present description of the study area and methodologies employed. The fourth chapter provides data presentation and analysis while the fifth chapter is about finding and discussion and the six chapter finalizes with conclusions and recommendations drawn from the study finding.

CHAPTER TWO

LITERATURE REVIEW

Introduction

The conceptual framework of the paper shows that the literature review shall focus on three major issues: Housing, The Housing supply process and the supply process's failure management system.

2.1 Housing

Housing refers to houses or buildings collectively, accommodation of people, planning or provision of accommodation by an authority and related meanings. Housing has several functions for society and individuals such as besides being a shelter; it provides protection and private space for its users, a social space for the households and a space where social relations with the society are continuously reproduced. A basic human need, housing offers refuge, safety, and a basis for social interaction. It includes social, economic, and cultural elements in addition to physical structures. Although the UN recognizes access to decent housing as a human right, issues with affordability (Cost), sustainability (Quality), and urbanization continue to exist on a worldwide scale. Housing affordability is not simply a matter of housing costs and household income levels. It is also about a household’s ability to obtain housing and then to retain it. It is important that households have sufficient residual income to purchase other necessities after paying their housing costs (Chowdhury 2023).

Housing is considered affordable if expenditure relative to income is reasonable or moderate. Nowadays Housing Affordability is an important term all over the country Various Countries has various concept and situation on housing affordability and maximum countries are facing severe problem of this. It is necessary to understand the problem and solve it. Countries are now dealing with this problem through adopting housing policies and various steps. Housing is one of necessities of life. Housing transcends physical shelter but determines even social, physical and

psychological well-being of man. Housing development and delivery is a critical aspect of provision of shelter as it involves a chain of processes and commitment from site acquisition to construction and final occupation or disposal. Housing is a complex product that is crucial for national development in terms of both economy and welfare.

From the perspective of residences preference and choice according to their financial status housing can be defined as a mass-produced consumer product, human use values must be substituted for material values. It also states that; housing problems were defined as functions of mismatches between people's socio-economic and cultural situations and their housing processes and products; and as functions of the Waste, mismanagement, or non-utilization of housing resources. It argues that housing should not be stated in terms of standards unit deficits, housing solutions can no longer be proposed in terms of unit production or productivity (Turner 1976)

Housing problems in Ethiopia

Ethiopia is Africa's second most populous and fifth least urbanized country. According to the most recent data, 21.3 % of the population is urban (24,463,423 people in 2020) or about 24.5 Million people reside in urban areas in Ethiopia, out of a total population of 118,852,589 based on World meter elaboration of the latest United Nations data, (2021). Ethiopia's urban population is much lower than that of Sub-Saharan Africa, according to national classifications. The urban population of Sub-Saharan Africa is 40.4 percent, and it has expected to grow significantly over the next few decades. The ESS projects that the urban population will increase to 42.3 million by 2037, growing at a rate of 3.8 percent per year, while the World Bank projects a higher rate of 5.4 percent per year (Surveyor Population and Housing, 2019). Ethiopia's urban population is quickly growing. Ethiopia has more than a quarter of its population living in urban areas, with an annual rate of urbanization of 4.64 percent as a result of the country's total population living in urban areas reaching 34.5 million people in 2030.Projections from UNDP, 2018. The urban housing shortage in Addis Ababa has a number of negative consequences for city

people' livelihoods. As a result, urban housing is a requirement or aspect that has an impact on the well-being of city people. Recognizing the challenge, the government has implemented a variety of policies and projects, including the construction of an additional 2250831 housing units/225000 housing units each year/ to meet current requirements while also addressing existing backlogs (The World Bank, 2015). Due to waiting times, a lack of suitable upkeep, and reconstruction, the age of urban dwelling conditions is quite long and degrading. The shortage of urban housing is particularly significant due to poor infrastructure with low service, lack of adequate water, sanitation, and open space (GETACHEW 2016). In Ethiopia, there is a significant disparity in terms of both quality and quantity in the urban housing sector. In addition to replacement housing, demand for new urban housing has expected to exceed supply by 381,000 each year (MOUDH 2013). An uncontrolled flow of people from the countryside into the towns will very often result in deficient housing conditions.

According to the ESS July 2015 estimate, Ethiopia's total population is about 90 million people. Of the total population 19.5% (17.5 million people) live in urban areas. This number is rising fast due to an annual urban population growth of 4.89%. Ethiopia's urban population is expected to triple by 2037 (World Bank, 2015)19. Addis Ababa hosts an estimated 3.238 million people, which is a 17% share of Ethiopia's total urban population. Currently, Addis Ababa is experiencing an annual growth rate of 3.8% and is estimated to reach 4.7 million inhabitants by 2030. (UN-HABITAT 2017). Individuals has to be provided with housing that meets at least basic human needs.

Housing and Cost

It is clear that housing finance is one of the key components in housing development. It is one of the basic reasons for changing housing development strategies even in the global scale. It is a critical factor that determines the types, the process and success of the housing to be developed. There is no single type of housing finance system; it varies from country to country. (UN HABITAT, 2006)

Housing problems are largely to do with affordability housing is expensive and incomes are too low. Faced with few other options, vast numbers of households live in inadequate housing in slums and informal settlements because they cannot access better quality housing at affordable prices (UN-HABITAT 2011). Furthermore, in many cases, they pay an inordinate share of their income for such housing, and are further impoverished as a result. The urgent task is to make the urban housing sector in both large and small African cities function more effectively to increase access to affordable housing, especially for low-income households.

Addis Ababa, the capital city and economic hub of Ethiopia, has experienced significant population growth over the past few decades. According to the World Bank (2015), the city's population has surged from approximately 2.7 million in 2007 to over 5 million in 2022, driven by both internal migration and natural population increase. This rapid urban expansion has exacerbated housing demand, revealing critical deficiencies in the management and technology used in housing development and supply (Hailu 2024). To describe the housing affordability, housing price and income relationship is important. This factor leads to know the affordability of each person either to own or rent a house. The average income need to be addressed in order to support the debt for housing loan. Based on the examining salary of low and middle-income group, they are still facing the tight costs of living and could not own a house (Osmadi 2015). (Daud 2017) State that the private sector should not focus only on a profit margin. They should more encourage achieving the supply demand of affordable housing.

Cost management is a vital aspect of housing projects, and failures in cost control can lead to budget overruns and financial challenges.

- Cost Overruns: Cost overruns are a common issue in housing projects, often resulting from unforeseen expenses, scope changes, and inaccurate cost estimates. The research by (Flyvbjerg 2021) indicates that cost overruns are prevalent in construction projects due to optimistic budgeting and lack of contingency planning.

- Inefficient Resource Allocation: Inefficient allocation of resources, such as materials and labor, can lead to increased costs. A study by (Ghosh 2022) explores how suboptimal resource management practices and procurement inefficiencies contribute to higher project costs and financial strain.

- Economic Fluctuations: Fluctuations in economic conditions, such as changes in material prices and interest rates, can impact housing project costs. The work of (Miller 2020) underscores how economic volatility affects cost projections and budget management in housing projects.

Housing and time

Efficient time management and housing construction technologies are essential for expediting the building process and guaranteeing project completion on schedule. Technologies that takes too much time to be constructed

Time is a critical performance measure in the housing Delays in project completion can have far-reaching implications for housing availability and affordability.

- Construction Delays: Delays in housing construction can arise from various sources, including unexpected site conditions, supply chain disruptions, and inefficiencies in project management. According to the study by (Koushki 2022) Housing construction delays are often caused by poor project planning and coordination, which can lead to increased costs and extended timelines.
- Regulatory and Permitting Issues: Regulatory approvals and permitting processes can contribute to delays in housing development. (Chen 2023) discusses how bulky regulatory procedures and lengthy approval times can hinder project progress and affect the timely delivery of housing units.
- Labour Shortages: Labour shortages and skill mismatches can also cause delays in housing construction. A report by Africa in fact highlights how labour market fluctuations and inadequate workforce training can impact construction timelines and project efficiency.

Housing and Quality

Quality in housing and construction refers to making sure that a building is constructed in accordance with predetermined guidelines and standards, taking performance, durability, and safety into account. This entails utilizing the right materials, adhering to construction guidelines, and implementing quality control procedures all along the way. Quality is an essential performance principle in housing supply, impacting the durability, safety, and satisfaction of housing units.

- Deficient Construction Quality: Quality issues can arise from poor construction practices, inadequate materials, and lack of adherence to building codes. According to the research by (Olatunji, 2022) quality failures often result from insufficient quality control measures and inadequate supervision during construction.
- Design Flaws: Design flaws and inadequate planning can lead to functional and aesthetic issues in housing projects. A study by (Olatunji, 2022) highlights how design errors and misalignment with user needs can affect the overall quality and usability of housing units.
- Maintenance and Longevity Issues: The long-term quality of housing is influenced by maintenance practices and the durability of construction materials. The research by (Kibert 2021) emphasizes the importance of considering maintenance requirements and material longevity to ensure the sustainability and quality of housing over time.

Ensuring high-quality housing and construction is essential to building structures that are secure, long-lasting, and useful. It entails meticulous preparation, the use of premium materials, conformity to building codes, and continuous quality control procedures.

Housing and Technology

From what has been said above it is obvious that the Ethiopian society is facing a formidable task in the future: to meet the needs of a dramatically increasing urban population. It must be the aim to provide this population with decent and reasonable living conditions as regards housing, water supply, sewage systems, infrastructure,

electricity, waste-handling systems. Housing and housing construction technology are tightly intertwined, affecting everything from building speed and quality to affordability and sustainability. In the end, advanced construction technologies can result in quicker, more economical, and more efficient building processes, which will increase housing accessibility and sustainability. When putting these technologies into practice, it's important to take into account elements like labour availability, local resources, and environmental effects. The way homes are planned, constructed, and maintained is changing as a result of the interaction between construction technologies and housing, especially when it comes to tackling global issues like labour shortages, affordability, and sustainability. A thorough examination of how new technologies are changing the housing industry may be found below.

The development of housing technology is a fascinating trip that reflects the evolution of humankind from simple shelters to intelligent, environmentally friendly structures. Technology improvements have influenced our built environment by tracking significant breakthroughs from prehistoric times to contemporary inventions. Housing technology encompasses a wide range of technologies used in the building industry, from traditional methods to advanced digital tools. These technologies aim to improve efficiency, safety, and cost-effectiveness. Housing Technology project can be seen as Traditional Construction Types which are characterized by Conventional Materials, Manual Construction Techniques, Design and Architecture including technologies that are- reinforced concrete, Adobe (earth brick) and Sand bag technologies. Advanced Housing Technology innovations provide a route to increased sustainability, efficiency, and competitiveness, with the use of cutting-edge tools and construction methods; it will be the ones creating a more promising and sustainable future as technology develops. Includes Prefabrication and Modular Construction, 3D House Printing, can be promising.

2.2 The housing supply process

The quantity of available housing units in a given geographic area, including both newly built and existing residences, is referred to as the housing supply. It is the

entire amount of real estate that is offered for sale or rental at a specific price right now. Analyzing affordability, market dynamics, and the effects of different policies on housing prices all depend on an understanding of the housing supply. This process is sequential and interdependent, with each phase provision of land, finance and technology influencing each other.

The housing supply is strongly linked to Demand inputs refer to the factors that drive the need for housing. These include demographic trends, economic conditions, and consumer preferences. Changes in population size and composition significantly influence housing demand. According to (Glaeser 2021) urban population growth and demographic shifts, such as aging populations and increasing household sizes, impact the demand for different types of housing. For example, younger populations may drive demand for rental housing, while aging populations may increase demand for accessible and supportive housing options. Economic factors such as income levels, employment rates, and interest rates play a crucial role in shaping housing demand. Higher income levels generally lead to increased demand for homeownership and higher-quality housing (Chen 2023). Conversely, economic downturns and high interest rates can reduce housing affordability and dampen housing demand (Miller 2020).Changes in consumer preferences and lifestyle choices also affect housing demand. The rise of remote work and increased interest in suburban or rural living has altered housing preferences in many regions (Glaeser 2021). Additionally, preferences for sustainability and energy-efficient housing have influenced the types of housing that consumers seek.

Housing supply requires its supplier the Government and the private sector developer. Further the literature will take a look at Understanding these components and essential for addressing housing technologies.

Land Availability

Land availability is a fundamental factor affecting housing supply. The accessibility and usability of land for development have significant implications for the pace and scale of housing construction. Shortage of land for the development is caused by

the high population, rapid urbanization and poorly conceived policy and regulations (Gopalan 2014). Similarly (Ugochukwu 2018) viewed that the inaccessibility to the land caused the reduction of affordable housing provision. Scarcity of available land may contribute to the problem of high land prices, crowded neighborhoods and the squatter settlements.

Land Use Regulations: Zoning laws and land-use regulations heavily influence the availability of land for residential development. (Fischel 2022) discusses how restrictive zoning practices can limit the supply of land available for housing, leading to increased housing costs and reduced affordability. Regulatory frameworks that restrict density or impose extensive land-use restrictions can inhibit new housing development and contribute to supply shortages.

Urban Expansion and Land Scarcity: As urban populations grow, the competition for land in metropolitan areas intensifies. According to Glaeser and Gyourko (2021), urban expansion often leads to higher land prices and increased difficulty in acquiring land for new housing projects. Effective land-use planning and strategies for densification are crucial in addressing the challenges of land scarcity.

Brownfield and Greenfield Development: The choice between developing on brown field (previously used) and green field (undeveloped) sites can affect the cost and feasibility of housing projects. Studies indicate that while brown field development can mitigate some land-use issues, it often involves higher remediation costs compared to green field development.

Finance

Financial resources are critical to the housing supply process, influencing both the ability of developers to undertake new projects and the affordability of housing for consumers.

Various financing models impact the housing supply, including public funding, private investment, and mixed-financing approaches. The Low-Income Housing Tax Credit is an example of a successful public-private partnership that has facilitated affordable housing development in the United States (Cunningham 2014).

Innovative financing models, such as community land trusts and real estate investment trusts, are also explored as mechanisms to enhance housing supply (Clark 2021).The availability of credit for developers and homebuyers is a significant factor affecting housing supply. Economic downturns and changes in interest rates can influence lending conditions and impact the ability of developers to finance new projects. (Chen 2023) highlight how fluctuations in interest rates can affect housing demand and supply by influencing borrowing costs and mortgage affordability. Global material shortages can inflate costs. Local sourcing and alternative materials mitigate this. Government subsidies and incentives can support housing development by reducing costs and encouraging investment. Policies such as tax incentives for developers and subsidies for low-income households can enhance housing affordability and stimulate new construction (Miller 2020)

Housing technologies in current practice and the future alternatives

Housing supply encompasses technology the methods and materials used in building housing, impacting the cost, time (speed), and quality. Due to time technologies are dividing in to traditional and Modern way.

Traditional construction methods, while well-established, can be labor-intensive and time-consuming. Modern construction technologies, such as modular and prefabricated building techniques, offer potential benefits in terms of cost efficiency and construction speed. (Sass 2022) discusses how advancements in technology can lead to more efficient building processes and improved housing supply. Innovations in housing technology also focus on sustainability. The adoption of sustainable materials and techniques contributes to more resilient and environmentally friendly housing solutions. Technological advancements such as 3D printing and automated construction processes are emerging as potential game-changers in the housing industry. These technologies have the potential to reduce construction costs, shorten project timelines

The responsiveness of housing supply to changes in demand affects market equilibrium. Elastic housing supply, where developers can quickly respond to increasing demand, helps maintain balance in the market. In contrast, inelastic

supply due to regulatory constraints or high construction costs can exacerbate affordability issues during periods of high demand (Glaeser & Gyourko, 2021).The Housing Market Cycles: The housing market is subject to cyclical fluctuations influenced by both demand and supply factors. Economic cycles, interest rate changes, and shifts in consumer preferences can lead to boom and bust cycles in the housing market (Miller & Skidmore, 2020). Understanding these cycles is essential for developing and implementing modern technologies policies that stabilize the housing market and promote long-term affordability Considering time, cost, and quality in a holistic manner. In the following section different technologies are discussed on how to achieve this goal. The emphasis is put on 3D technology in to work as the authors regard this technology as the most promising one for the future.

1. **Concrete hollow blocks(Conventional housing technology)**

Conventional housing describes conventional building practices that use generally recognized materials and procedures, frequently standardized within a particular area or nation. Mostly steel, wood, glass, concrete, and brick. Depends on hand labor to complete activities like framing, finishing, and bricklaying. **(foundation → framing → roofing → utilities)** make up the linear house building process.

Building a conventional single-family home (Occupied by one house hold and detached to no other buildings) typically takes 6 to 13 months from start to finish, though timetables might vary depending on geography, weather, permits and project complexity. The process can be lengthy, particularly if there are weather delays or material shortages. Requires a high level of competence, which can be difficult in some areas. Potentially more expensive than other approaches, especially when labor costs are significant. Waste Generation Can result in more waste than more efficient construction methods.

Figure 1 : Convention Housing construction

Source: - https://injarch.com/traditional-construction/

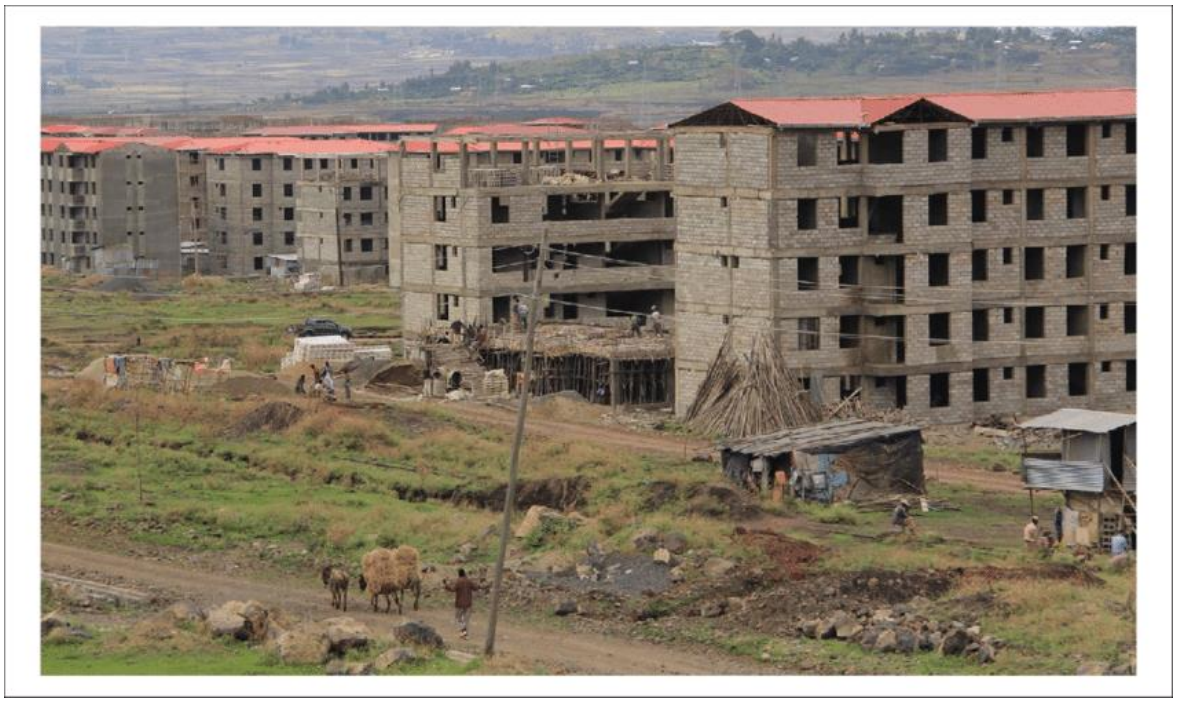

Figure 2: Conventional Housing

Source: - https://images.app.goo.gl/haYMZ1kNcTr4mmAt6

2. Mud Block(Adobe Block)

According to (Dagnachew 2020) mud block constructions are more energy efficiency, environmentally adaptable, sustainable, recyclable, uses local material and labor, and ease of construction. As studies show the major factors affecting the quality of the mud block houses were soil, stabilizers/admixture, moisture/rain, and the use of structural elements. The block molded from clay soil, and stabilized with cement and sand can stand for long years while block molded from silt soil and sand soil stabilized with straw can survive for more than 30 years. Besides the soil type, the building height affects the durability of the mud block houses. The ingredients used for molding mud block were soil, and stabilize (cement, sand, and straw) and the types of the soil and stabilizers have the greatest impact on the strength of mud blocks.

The durability, construction technique, and adaptability of mud block housings are different from place to place depending on the climate, soil type, stabilizers, resource availability, technology, and economy. Building of mud block houses the structural elements are not mandatory for construction of durable sustainable houses (Dejene B & Dagnachew A(2020).

Adobe bricks are highly susceptible to erosion and deterioration when exposed to water, especially in areas with high rainfall or humidity. Without proper protection, the bricks can soften, crack, and even collapse over time. They are not waterproof and require regular maintenance, such as applying moisture-resistant coatings. Mud block housing construction minimizes the use of wood product and energy inefficient material for construction that result in the good environmental and economic living world. Thus Mud block construction is more advocated for warm areas due to low access to wood, good cooling effect, and low moisture or rain (Dejene B & Dagnachew A(2020).

Figure 3: Mud Block Housing Construction

Source: - https://www.urbunhut.com/image/bt6.jpg

3. Aluminum Formwork Technology

Aluminum formwork is a construction material made of aluminum alloy used to mold and support concrete during pouring. It's a lightweight, reusable, and corrosion-resistant alternative to traditional wooden or steel formwork. Aluminum formwork systems allow for monolithic pouring of concrete structures like walls, slabs, and stairs.

The application of aluminum formwork technology in construction engineering can take advantage of its own small weight, it can conveniently support system, simple operation control, short construction period, high strength, stability and carrying capacity, which is beneficial to the improvement of the overall building quality. Firstly, the weight of the aluminum template is small, which can improve the operation efficiency of the construction. When it is applied to the pin of the connection system, the utility model has the advantages of convenient disassembly

and assembly, and only manual transportation is required in actual operation, thereby eliminating mechanical expenses. (Zhang 2022).

Figure 4: Aluminum Formwork Housing Technology

Source:https://www.alcirclebiz.com//Uploads/ProductCategoryImage/Building%20and%20Construction%20Casting_09122024133017.jpg

Aluminum formwork has a short construction period and is easy to assemble and disassemble. Only one set of templates is needed for the entire project, which effectively reduces the construction cost. Certainly, the application of aluminum formwork in the construction of the house can also effectively reduce the construction cost. This is because the aluminum formwork can be reused. A set of aluminum formwork can be recycled .The environmental protection effect is very good, and the cost of the overall engineering is reduced. (Zhang 2022)

4. Pre-fabricated Housing Technology

Prefabricated housing technology, also known as modular construction, involves the off-site manufacturing of building components and their subsequent assembly on-site. This construction technique offers numerous advantages, including reduced construction time, cost efficiency, improved quality control, and sustainability. According (Ghosh, 2022) to (Alviano, 2019).pre-fabricated house is a house

building whose components are ready in the form of finished goods produced by the factory. So the pre- fabricated housing technology is an appropriate solution to reduce development costs, reduce development time and reduce the inefficiency of a typical residential house which is certainly more expensive than modular. Modular housing has a unique system and is certainly fast in the development process, usually a technology that is paid at a high price, but innovation is not always expensive.

The technology has software and design, fabrication and cold forming as well as site installation and erection components. The technology transfer will work out towards enabling Addis Prefab to be competitive in the field of light steel framing as the plant will be the first of its kind in Africa. According to the company believe, it has taken a major stride to achieving its goal in becoming the largest manufacturer and supplier of light steel framing solutions in the region. It has also licensed to supply the technology to the whole region of East, Central, West and South parts of Africa.

- Prefabricated housing techniques are known for reducing construction time significantly. According to (Gibb 2020), these methods allow for the simultaneous construction of building components off-site and on-site, leading to faster project completion. Modular construction, in particular, can cut construction time by up to 50% compared to traditional methods (Smith 2022)
- (Gibb 2020) report that these methods can lower labor costs and reduce material waste, leading to overall cost savings. However, initial setup and transportation costs can be higher, which is balanced by long-term savings.
- Prefabrication improves quality by ensuring precision in manufacturing and reducing on-site errors. A study by (Mo 2023) demonstrates that modular units often exhibit higher quality due to controlled factory conditions and standardized processes.

Figure 5: Pre-fabricated Housing Technologies

Source; - https://www.bilkaprefabrik.com/en/wp-content/uploads/2023/05/Materials-of-Steel-Prefab-Houses.jpeg

5. 3D Housing printing

By making construction rapid and flexible, 3D printing (3DP) technology has been gradually accepted as a prospective way to revolutionize home design and construction. Three-dimensional-printed houses represent a ground breaking shift in building, and the process is actually not that complicated. Industrial-sized 3D printers build life-sized houses layer by layer, which is commonly referred to as additive manufacturing. These printers follow a pre-designed digital blueprint and dispense a cement-based mixture through a heated nozzle. Then, the mixture is solidified by a concrete dryer before applying the next layer, and this process repeats itself until the design is realized. In terms of materials, there's a variety of options other than cement, such as polymers, sand, resins, and even sustainable

alternatives like hemp Crete (wood core of tree) and wood composites. The technology of construction 3D printing is the application basis of the internet in the construction field. The buildings built under 3D printing technology are called 3D printing construction. If the cost of the 3D printing construction is low or the output efficiency is far greater than the input, the 3D printing technology will be easily accepted by many enterprises in the construction field. Only when we understand the 3D printing construction cost can we accurately plan the development strategy of the internet of things in the construction industry. And the following is to solve the problems of cost accounting method to 3D printing construction.

The construction 3D printing (C3DP) was first introduced by James B Gardiner in 2011 and refers to buildings constructed with the 3D printing technology. There are two types of 3DP. That is onsite and offsite 3DP. In offsite 3DP, the units or components are printed in the factory and then transported to site for assembly. In onsite 3DP, the units are constructed at the site directly. Currently, there are some cases of 3D printed buildings. The Chinese company Yingchuang had successfully printed the office buildings in Dubai, and Huashang Luhai Ltd. had printed the first integrated non-modular house in Beijing. The 3D printing is a new technology which shows its advantage in building irregular buildings.

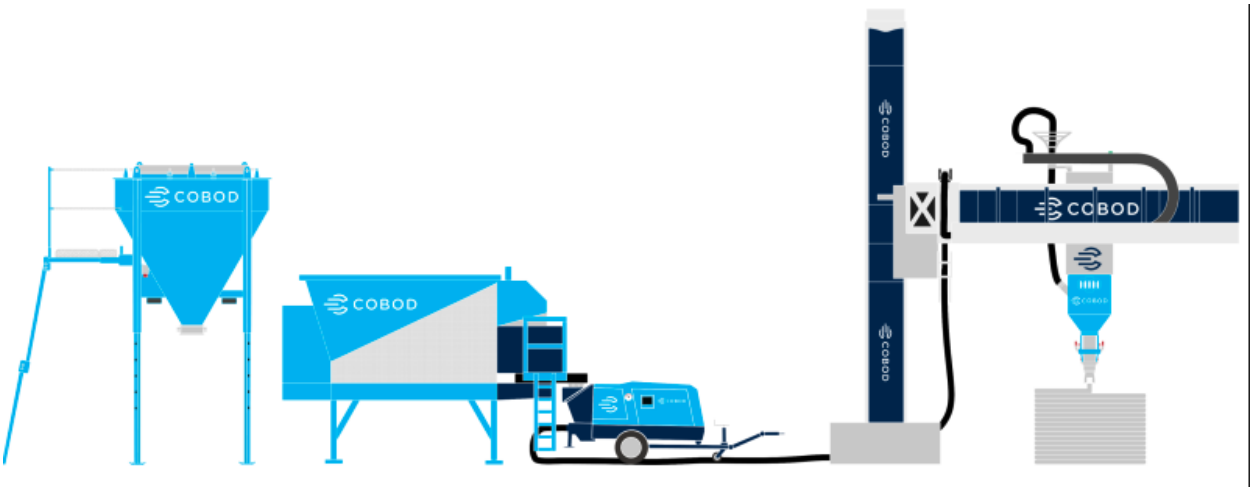

Figure 6: Model 3D Printing Machinery Set up

Source:https://web.facebook.com/photo/?fbid=661423753078264&set=a.173463801874264

Figure 7 : 3D House printing Process

Source: - https://images.app.goo.gl/SDzivRudArMVMvby9

Figure 8 : 3D printed House in China

Source: - https://images.app.goo.gl/bPY9YySoYFyC1Zby7

A 1,200 sq. ft. home is being 3D-printed in Nome, Alaska, using a mobile off-grid system. The project addresses challenges like permafrost and extreme weather with innovative foundations and locally sourced materials. Lennar ICON built 100 homes in Georgetown, Texas, with 75% sold. Using 11 robotic printers, they reduced construction time by half, printing two homes/week. Costs dropped by 50% in subsequent projects 58 Companies like Mighty Buildings in California use 3D-printed thermoset panels (60% recycled materials) to assemble homes in 2–3 months, reducing waste by 99% compared to traditional methods. (Lennar 2024)

The construction process is autonomous, but human oversight remains crucial to ensure quality control. Specialists must be onsite for complex tasks like plumbing, electrical wiring, and the installation of doors and windows. As for the size of a 3D-printed home, it can span from small prototypes, affordable housing, and luxury homes to whole neighbourhoods. Not only does this type of computerized construction reduce waste and labour, but it also solves several pressing issues, such as creating shelters for communities and sustainable housing solutions. (Yohannies 2025)

Figure 9: 3D printing on Process of building House

Source: - https://parametric-architecture.com/wp-content/uploads/2022/10/CE-Industrial-Services-3d-printed-cover-2.jpg

The United Arab Emirates is making strides with company named ICON's Technology behind the world's largest 3D-printed building in Dubai. The UAE is heavily investing in 3D printing technology, aiming to have 25% of all new buildings constructed using this method by 2030.

The cost of a 3D house printer can vary, ranging from a few thousand to hundreds of thousands of dollars.COBOD reports that some 3D house printers are as big as construction equipment, with prices reaching in $220,000 (Ethiopian birr 29,704,400). However, smaller-scale printers for construction parts can be found for $3,010-3,207 (Ethiopian Birr 406,410.2- 433,009.14).while specialized concrete printers can range from $10,000 to $20,000 (Ethiopian Birr 1,350,500-2,701,000)

The literature highlights successful case studies and best practices from other regions or countries that have implemented affordable housing technologies. It draws insights from these experiences to provide recommendations and lessons that can be applied to the context for low and middle income society. Sustainable and Resilient Housing: The review emphasizes the importance of sustainable and resilient housing in the face of environmental challenges and climate change. It discusses the integration of green building principles, renewable energy systems, and disaster-resistant technologies as crucial components of affordable housing systems for low and middle income society.

Overall, the literature review provides a comprehensive overview of the practice and challenges of technologies for affordable housing systems for low and middle income society. It highlights the significance of policy support, stakeholder engagement, socio-economic factors, and sustainable approaches in addressing the housing needs of the city's population while considering affordability and long-term sustainability.

2.3 The Process Failure Management System

Managing housing supply process failures can be a complex challenge that requires collaboration between government agencies, private sector, and community stakeholders. When it comes to managing alternative housing technology supply process failures, it's important to properly identify the root cause of the failure. It's crucial to assess what went wrong and take corrective actions to prevent failures in.

In the case of alternative housing technology providers for lower-level city dwellers, the private sector should be in line for housing supply but in any case if the private sector fail to supply the government should supply housing .some common failures in the housing supply process that may need to be managed by the government include issues related to Government scope, strategies used to and instruments implanted to address housing challenge. Effective management strategies are crucial for overcoming failures in the housing supply process. These failures, which can manifest as delays, cost overruns, and quality issues, impact the affordability,

availability, and quality of housing. This literature review explores various management strategies designed to address these failures. By examining successful approaches and best practices, stakeholders can better navigate the complexities of The housing supply process can face several failures when it comes to alternative housing technology providers for lower-level city dwellers. Some of these failures include:

Coordination is challenging due to the fragmented management of the housing supply across multiple government departments and organizations. The process gets disjointed in the absence of an integrated framework, which results in inefficiency and Corruption. Which weakened the efficacy of the housing initiatives and the local government lacks technical expertise, particularly when it comes to sophisticated project management, planning, and technology integration.

Scope

Policy and regulatory frameworks play a crucial role in facilitating the implementation of housing technologies. Policy and regulatory frameworks provide the necessary support, guidelines, incentives, and partnerships to facilitate the implementation of housing technologies. They promote innovation, establish standards, address financial barriers, streamline approval processes, foster collaboration, and address regulatory obstacles, and enable monitoring and evaluation. By creating an enabling environment, these frameworks play a pivotal role in advancing affordable and sustainable housing solutions.

Strategies

There have been different housing development strategies to address the issue, housing. The evolution of housing policies, objectives and policy instruments has been shaped by economic ideologies, experiences and international development agendas and other contextual issues. (Tibaijuka 2013)

Housing as social good: 1960and early 1970

The intention of the strategy, governments must intervene in the formal housing market to support the lower income groups to have a dwelling which have good quality; fully serviced with permanent construction material (Wakely 2014) is a positive idea. But, the strategies have proved to be inadequate to address the issue due to the following two main reasons:

- Governments faced difficulty to provide adequate shelter due to economic, social and political pressures. Especially, in the rapidly urbanizing cities of the developing countries with a huge amount of housing demand and limited resources.
- The cost of the houses rose beyond the expected, the poor's were excluded and only the middle income and high incomes afford the houses. This created serious social displacement and disruption for the residents of the slums, imposing transportation cost to the relocated society from their work place, the center of the city. (UNCHS, 1987: as cited by (Bekele 2003)

Self-help approach: 1970s-mid 1980s

Strategies to support self-help ownership on project basis through two programs: slum upgrading programs and site-and-services provisions (SSPs). The first is intended to improve housing conditions of existing slum settlements whereas the second is intended to address new demands and backlogs. It was a shift from direct public-sector house provision to self-help, to distribute the burden of the government to other actors, mainly to the people (Tibaijuka 2013). The programs had brought positive changes and outcomes like maintaining the economic organization and social networks of the society, avoiding relocations, empowering the poor to decide on housing priority/type and give the chance to incremental development i.e. more affordable shelter for the urban poor. But, with all the positive changes and outcomes the programs had faced one basic problem, continuity. I.e. The programs were put in place through a huge amount of subsidy sometimes reaching 65% or more (Keare and Parris, 1982 as cited by (UNCHS 2001). This had

paused resource limitation which created difficulty to address the whole housing problem. In general, the projects of slum upgrading and SSS of the 1970s proved to be inefficient use of scare government or international resources, fund which was mainly acquired from World Bank, donors and low credit facilities. (UNCHS2001) It also failed to be replicated by private sector [market] in order to eliminate housing subsidies and be sustainable. (Bekele, 2003) In addition, even with such subsidies it has been observed that it was still inaccessible to the poorest households. (Bamberger, 1982 as cited by UNCHS, 2001)

The enabling approach: late 1980s-early1990s

One of the basic changes in the enabling approach is the role of governments. Withdrawing from the direct provision of housing governments focused on establishing legal and institutional frameworks that create comfortable grounds to facilitate and the efforts of others and enable them to mobilize their full potentials and resources. Some of these enabling schemes are: governments reduced policies and regulations that impede the production of housings, preparing incentives that invite and attract different actors to engage in housing production (Bekele, 2003).

The approach laid partnership as a fundamental element for the success of the strategy. (UN HABITAT, 2005) It stress on new partnerships to be developed between different actors in the housing development process: governments, the private sector, NGOs and community based organization and the people/household themselves to maximize efficiency. Under the concept of partnership the approach also intends to engage the private sector and encourages reliance on market actors for housing production. (UNCHS 2001) This addresses one of the basic drawbacks of the previous strategies and reliability. Under the concept of partnership the approach also aim at promoting self-administered community based organization, NGOs ... as one of the major actors.

Sustainable settlement development since 1990s on wards

As it can be inferred from the above literatures, housing strategies and approaches were highly influenced by the general development paradigm. In the course of time the day for economical paradigm changes and fades due to two factors: firstly it fails to meet its goals even if it was applied for decades and secondly a new and expanding concern and knowledge about environment emerged and accumulated. This leads to the crystallization of a new developmental paradigm, sustainable development, a general global development consensus (Sachs, 1999). This sustainable development paradigm includes multiple issues of which housing is one.

Strategies Practice

Site and services

Site and Services is a strategy used to address housing shortages, particularly in developing countries, by providing affordable, serviced plots of land to low-income households. Instead of offering fully built homes, governments or developers offer a "site" (a plot of land) and basic "services" (infrastructure like roads, water supply, sewage, and electricity). Families are then responsible for constructing their own homes at their own pace. Similarly cooperatives have got attention through the facilitation of developed land, standard typologies, etc. Protecting the construction of illegal houses or those does not confirm to the standard and plan has got emphasis in the policy.

Integrated housing development Program (Condominium)

Through the adoption of several housing projects and initiatives, the Ethiopian government has attempted to solve the housing gap. Large-scale public housing initiatives, such the "10/90,20/80 and 40/60 housing scheme," which allocates higher numbers were from the government aide and lower numbers are for people who are in need of housing units which have been implemented as a main tactic. Despite these efforts, there are still a number of challenges facing the government,

such as: Challenges with Implementation: The home supply process is delayed and lacks coordination due to the bureaucratic inefficiencies of municipal governments and urban planners. Poor Monitoring and Data Management: Making informed judgments is made more difficult when housing supply management is plagued by a lack of effective real-time data and monitoring systems**.**

National urban development policy in Ethiopia is issued in 2005, which are developing the construction industry, through the implementation of IHDP. The government intervention in line with facilitating housing finance, land, capacity building, bulk purchase of industrial product of construction material, organizing medium and small scale enterprises, introducing new construction technology that minimize cost and time, standardizing the housing could be mentioned. The policy also encourages real estate developers through the facilitation of developed land, strengthen the system for ensuring property rights, supporting the developers to utilize local materials, marketing and create forums of discussion for sustainable problem solving and encourage the investors. Similarly cooperatives have got attention through the facilitation of developed land, standard typologies, etc. Protecting the construction of illegal houses or those does not confirm to the standard and plan has got emphasis in the policy (Tameru 2010)

IHDP which was undertaken in 2006 showed that the housing shortage within the populated area of the country is 900,000 out of which 450,000 was found in Addis Ababa alone. The town administration has introduced the condominium housing program within the city to boost the housing condition and to unravel the housing scarcity. This can be often outpaced by the estimated demand of 471,000 and 486,000 units annually till 2025 and 2035 respectively. IHDP can be a large-scale approach to addressing this housing shortage. But it's criticized it for its failure to meet the residents need and expectation starting from design till the implementation or delivery stage.

The 70/30 housing development scheme

The 70/30 housing program is innovative approach aimed at helping residents build condominiums through associations. This initiative comes as a response to the limitations of previous city-led housing projects that have struggled to meet the rising demand for affordable housing in Addis Ababa. The 70/30 housing scheme is especially geared towards residents who are already registered and waiting for condos under other city housing projects. It offers an alternative solution for those who have been affected by the delays and shortages

- Land Allocation: The city cabinet approved the allocation of 35 hectares of land for the new housing scheme. The land will be used to construct G-9 and G-13 condominiums, specifically designed for the program by the Addis Ababa Housing Development and Management Bureau (AAHDMB).
- Resident Contribution: Under this program, residents are expected to save 70% of the total cost of their flats. This self-financing model encourages long-term savings and participation in the construction process.
- Financing Support: The remaining 30% will be covered through long-term credit provided by the Commercial Bank of Ethiopia, following an agreement signed with the city administration in Decembers.

Instrument (Regulation and technologies) in Housing Supply Management

Developing a digital platform for managing housing applications, construction monitoring, and housing allocation can streamline the process and ensure better accountability and transparency. Policy and regulatory frameworks play a crucial role in facilitating the implementation of affordable housing technologies. Policy and regulatory frameworks provide the necessary support, guidelines, incentives, and partnerships to facilitate the implementation of affordable housing technologies. They promote innovation, establish standards, address financial barriers, streamline approval processes, foster collaboration, and address regulatory obstacles, and enable monitoring and evaluation. The government intervention in line with

facilitating housing finance, land, capacity building, bulk purchase of industrial product of construction material, organizing medium and small scale enterprises, introducing new construction technology that minimize cost and time, standardizing the housing could be mentioned.

One approach to addressing process failures in alternative housing supply is to conduct a thorough post-mortem analysis to understand what went wrong and why. This involves reviewing the entire process from start to finish, identifying any bottlenecks, inefficiencies, or gaps in communication that may have contributed to the failure.

In the case of alternative housing technology providers for lower-level city dwellers, some common failures in the housing supply process that may need to be managed by the government include issues related to land acquisition and zoning regulations, lack of supportive infrastructure such as water and electricity connections, insufficient access to financing for affordable housing solutions, and challenges in ensuring quality control and compliance with building codes.

The housing supply process is summarized as follows:-

1. Limited access to financing: Lower-level city dwellers may face challenges in accessing the necessary financing to afford alternative housing technologies. This can be due to a lack of credit history, income instability, or other financial barriers

2. Infrastructure challenges: Alternative housing technologies may require specific infrastructure support, such as access to utilities or transportation, which may not be readily available in lower-level city areas.

3. Resistance to change: Lower-level city dwellers may be resistant to adopting alternative housing technologies due to lack of awareness or familiarity which can slow down the adoption of alternative housing solutions.. The government could implement education and outreach programs to promote the benefits of alternative housing options.

4. Sustainability concerns: Alternative housing technologies should also be environmentally sustainable. The government should encourage and incentivize the use of sustainable building materials and practices in the construction of alternative housing for lower-level city dwellers.

5. Monitoring and Evaluation: The government needs to establish mechanisms for monitoring and evaluating the quality of housing provided by alternative technology providers. This can help identify any issues or shortcomings early on and take corrective action as needed.

CHAPTER THREE

RESEARCH METHODOLOGY

The particular goals of this research outlined earlier necessitate the use of Qualitative methods is primarily used to gather in-depth insights and perspectives from key stakeholders involved in the housing supply process such as interviews, document analysis, discussions. The research design will be a case study approach, focusing on the specific context of housing supply in Addis Ababa.

3.1 Data, source and collection methods

Document review

Data is collected mainly from housing and land policy, housing strategies and housing programs that housing supply provide, housing supply process applied technologies such as Concrete hollow blocks, Aluminum Formwork, Pre-fabricated Housing, Concrete and Qacha Housing Technology, Mud Block (Adobe blocks) and 3D Housing Technology. The data collected from housing supply failure, types of technologies to be studied and the types of failures (gaps) that require to be managed. The data collected from the preliminary report on the research on issues of housing supply failure were focused on issues such as mentioned on the research problems.

Interview and discussion

Interview and discussion data were collected from government bodies responsible for accepting and licensing the technology developers and housing supply process failure management system in order to answer the questions relating to the management system and its gaps as per the topic. They were also collected from the housing supply side which included 6 (six) technologies companies on issues such as the housing supply process, the housing supply process applied technologies and it also includes observation. One-on-one discussions with the technologies supply side took place.

3.2 Technology selection criteria

The case study focused on Addis Ababa, the capital city of Ethiopia, as a representative example of urban transition challenges and housing supply process failures. The selection of specific technologies reinforce concrete, Aluminum formwork, Prefabricated technology, concrete and Qacha construction technology, mud blocks construction technologies, and 3D housing printing construction technology was selected based on their –

- current operating systems
- mass housing technology
- works for low income demand side
- Technology data relevance and significance in the context of Addis Ababa.

3.3 Data Analysis

The collected data was analyzed to identify the root causes of the technology gap in the management system of Addis Ababa's housing supply process. This involves the three sets of data type by analytical framework. The data on the housing supply failure were analyzed by using the analytical frame work of cost, time and quality. The data on housing supply process were analyzed by the demand side that have gained access via the applied technologies considering issues cost ,time and quality whereas the data on of application of 3D printing technology uses the analytical frame work awareness gap, feasibility study gap ,study result gap, result implementation gap. The data on housing supply failure management system were analyzed by using mainly technical capacity inputs such as management regulation (scope), strategies, and enabled technologies.

The data on the primary solution were analyzed by using the issues of awareness gap, feasibility study gap, study result gap, result implementation gap.

The data on hosing supply process gaps were analyzed, as discussed above by using the following summarized analytical framework:

Table 1: Analytical Frame work with data type

Data type		**Analytical Framework**
Housing supply failure		Cost
		Time
		Quality
Housing supply process	Concrete hollow blocks, Aluminum Formwork, Pre-fabricated Housing, Concrete and Qacha Housing Technology, Mud Block (Adobe blocks) and 3D Housing Technology (Applied Technologies)	Cost
		Time
		Quality
	Gaps of application of 3D printing technologies	Awareness gap
		Feasibility study gap
		Study result gap
		Result implementation gap
The supply process failure management system	The existing management practice	scope
		strategy
		Instrument and enabled technologies
	Gaps of enabling the 3D printing technologies	Awareness gap
		Feasibility study gap
		Study result gap
		Result implementation gap

In general, the descriptive method of analysis was used to look at and understand the data that was collected from different sources. This could be done by classifying the data based on its purpose, summarizing it, and putting it into tables. Then the data was described in terms of what it is and what the summary means.

CHAPTER FOUR

DATA PRESENTATION AND ANALYSIS

Introduction

Population growth, rural-to-urban migration, and government-led infrastructure and industrialization have all contributed to Ethiopia's increasing urbanization in recent decades. Although it has created economic benefits, this fast urban growth has also presented gaps, particularly in the housing sector.

To address this housing gap throughout the period of history there have been different housing development approaches and innovations. From traditional to modern housing development innovation Housing supply plays a crucial role in ensuring the well-being and livelihoods of communities. However, failures in the management of the house supply process can have adverse effects on the overall quality, cost, and timeliness of housing projects. This case study examines the performance indicators of various alternative housing development technologies, including Conventional housing (Concrete hollow blocks), Aluminum Formwork, Pre-fabricated Housing, Concrete and Qacha Housing Technology, Mud Block (Adobe blocks) and 3D Housing Technology, by combining desk-based literature reviews, data analysis and interviews with technology providers. This thesis aim to identify the supply process gap of each technology type in terms of cost, time, and Quality

4.1 The Housing Supply failure in Addis Ababa

The housing supply failure in Addis Ababa, Ethiopia, is a complex issue driven by a combination of rapid urbanization, inadequate urban planning, limited financial resources, and institutional inefficiencies. Addis Ababa is experiencing a serious housing crisis marked by structural shortcomings in terms of price, timely delivery, and construction quality. Rapid urbanization, poor planning, and fundamental flaws in housing laws and financial institutions are the main causes of this complex

problem. Here is a thorough analysis of how Addis Ababa's ongoing housing supply failure is caused by the intersection of poor quality, high costs, and time delays.

Addis Ababa's housing crisis is first evident in the staggering gap between demand and supply. Projections indicate Ethiopia will need 486,000 urban housing units per year from 2025-2035, with Addis Ababa bearing a disproportionate share of this demand. This chronic undersupply creates intense competition for housing, driving up costs and encouraging substandard construction as desperate residents accept whatever shelter they can find. So this is where technology comes in line for better, faster and modern housing.

Cost

Cost represents perhaps the most significant barrier to adequate housing in Addis Ababa: Conventional housing options, including IHDP units and private sector developers, require a 20% down payment and high monthly mortgage payments that are unaffordable for the bottom 40% of income earners. Many residents spend over 30% of their income on housing, with some paying more than their entire monthly income just on rent. The private rental market features speculative pricing with the provision of new technologies and frequent unjustified rent increases, with landlords exploiting the housing shortage Even government-subsidized Kebele housing, while cheaper than market rates, remains inaccessible to many recent migrants due to long-term occupancy by existing tenants. This affordability gap pushes 80% of Addis Ababa's residents.

Time

Government-led housing programs and also private developer have consistently failed to deliver units in a timely manner Urban renewal projects to replace deteriorating housing stock proceed at a pace too slow to address both existing backlogs and new demand from population growth. Bureaucratic inefficiencies in land provision, permitting, and infrastructure development create significant delays, with some Housing provisions taking years longer than planned. These delays compound the housing shortage, forcing more residents to live in under

standardized homes. But when considering other technologies out of the ordinary much potential and design Flexibility will be gained.

Quality

70% of Ethiopia's urban housing stock does not follow to UN Habitat standards for spaciousness, durability, and tenure security. A large portion of the city's housing is made up of dilapidated, subpar Kebele flats that were built during the socialist era using wood and mud and are in dire need of renovation. One-third of all homes are in informal settlements, which usually lack adequate infrastructure and basic services. (UN-Habitat 2017) The private rental sector primarily provides subpar lodging, with tenants dealing with overcrowding, inadequate upkeep, and unstable lease terms. These problems with quality put residents' health and safety at risk while also not giving them the stability they need to grow economically. Encouraging innovative Housing development Technologies can be improved used as an option for better housing management.

Summarizing Supply failure in Addis Ababa

The majority of housing is financed by unofficial sources like savings groups and family, with only 23% coming from mortgages. Issues with urban government are delayed, especially when it comes to infrastructure and land provision. Private developers who may help meet demand have been overlooked in favor of government programs in housing policies.

4.2 The Housing supply process technologies

The tools, techniques, and innovations utilized in the planning, designing, building, and delivering of housing are referred to as "housing supply process technologies. “These innovations seek to raise speed, lower prices, increase efficiency, and improve the sustainability and caliber of housing developments. The main technologies utilized at various phases of the housing supply process are broken down as follows:

4.2.1 The Applied technology

CONCRETE HOLLOW BLOCKS (Conventional housing technology)

One alternative to the traditional technology described above is of course to use ordinary concrete hollow blocks for walls in dwelling houses. Although this technology must be regarded as rather advanced in many parts of Ethiopia it has apparently spread into many towns and can be regarded as well-known, at least in major urban centers.

It is obvious that if this technology is used durable dwelling houses that offer a good indoor climate can be erected. However this is on the condition that the ground conditions are suitable, that the building is provided with a proper foundation and that the walls are provided with reinforced concrete tie-beams and, in some cases, reinforced concrete columns. If all this is considered it is obvious that such a dwelling house must be regarded as rather advanced.

Even if concrete hollow blocks currently are manufactured locally in many urban centers in Ethiopia, this product cannot be regarded as a local material. As the cement is produced only in a few factories in the country, it has many times to be transported long distances. In addition to this it can be difficult to find sand, with a suitable grading and with a sufficiently low content of organic material, on the spot. Many times sand has to be taken from a river or from a lake rather far away.

The technology to use concrete hollow blocks for walls in houses is already an important technology in Ethiopia. It is reasonable to anticipate that its importance will be even higher in the future. However, it seems unrealistic to anticipate that it will be of a great importance as regards providing ordinary people in urban centers with proper housing. The reason is that it will not, in the foreseeable future, be “the property of everybody”. To erect a dwelling house with this technology will require special knowledge and special equipment and, above all, the cost will be comparatively high. The fact that cement is a key-material will be a major obstacle. The demand on cement at the Ethiopian market will be high for many years to come causing high price-levels for cement.

Figure 10: Construction materials and condominium housing in Yeka Abado
Source:https://www.manchesterhive.com/view/9781526171221/figures/9781526171214_C005_001.jpg

Aluminum Formwork Technology

Aluminum construction been in to work since 2013 and it's been 5 years since it started. The housing project has Motto saying "Housing for all" different place in Addis Ababa one is in bole BulBula, Gerji, Gelan Gura ,Bole Arabasa ,lideta ,kasanchess, Aware and Bahir Dar city. And developed more than 100 blocks .The supply process for the technology land is provided by Government and public private partnership, the housing design is performed in house design team and can be consulted based on the need of the interest group. The housing programs of this group or technology provides housing need based on the bed room 1bed room ,2bed room and 3 bed room and luxury villas and has includes subsidiary with bank.

The technology

Aluminum form work technology manufacturing process starts from developing of modular panels which are imported from china used produced but in our case the panels are being imported. These panels are made from aluminum alloy, which provides the advantages of being lightweight, durable, and easy to handle. The design of aluminum formwork panels depends on architectural plans of the housing project. The panel defines size, shape and layout of the formwork panels.

There are a number of advantages that correspond with market trends. It allows for quicker construction cycles since walls, slabs, and beams can be quickly assembled and reused, which cuts down on successive construction delays. Although aluminum form work requires a larger initial expenditure, it reduces long-term costs. Less reliance on labor and waste of materials despite its benefits, certain challenges have been noted. Aluminum formwork systems offer limited flexibility for custom architectural designs because of their uniform panel sizes and high upfront costs, which make them less feasible for small-scale projects. Inexperienced personnel may result in defects; proper supervision and assembly are essential. Large aluminum panels must be carefully planned for and stored in the right area.

Aluminum formwork Housing Technology Performance

Performance Indicators:

- High initial cost with cost savings in the long term
- Reduced construction time
- Precise construction and quality finishes

Aluminum Formwork Technology is characterized by high initial costs with cost savings in the long term. It offers reduced construction time and precise construction with high-quality finishes. Aluminum Formwork Technology has demonstrated significant potential in improving construction efficiency and ensuring high-quality outcomes. By 2-3 months 7 building has been developed in aware site

by government initiation. G+15 building in Bahir dar has been developed in 6 months with full completion of the building.

Aluminum Formwork performance by time

Aluminum formwork systems enable faster construction compared to Conventional methods, reducing overall construction time Excessive load or improper storage can bend panels, affecting concrete finish.

Aluminum Formwork performance by Quality

Aluminum Formwork Provides quality finishes and accuracy in construction. This technology is durable and can withstand various weather conditions. It requires less energy during construction due to its efficiency. The production can have environmental impacts such as increased carbon .while Exposure to moisture, chemicals, and harsh weather leads to have white rust.

Aluminum Formwork performance by Cost

Offers potential long-term savings as it allows faster construction, reducing labor costs over time. Aluminum formwork can have higher initial costs due to the material and technology involved. Despite increasing costs, aluminum formwork gives solution for large-scale and repetitive projects. However; cost-sensitive projects may require alternative solutions or financial strategies to maintain viability.

Figure 11: Houses built from Aluminum Form Work Technology Gerji site, Addis Ababa

Source:-Researchers own photo

Pre-fabricated Housing Technology

Pre-fabricated housing technology which is controlled by Ethiopian Construction Design & Supervision Works Corporation (ECDSWC) The housing project has a place in Addis Ababa one is in Akaki Kaliti which started building 5,000 housing units. The supply process for the technology land is provided by Government.

The technology

This technology uses pre-manufactured components or modules that are assembled on-site and produced in factory setting. Including building parts of the house off-site manufacturing and transporting them to the construction site for final housing assembly

Pre-fabricated Housing Technology Performance

- Higher initial cost
- Reduced construction time
- Good quality control and energy-efficient options

Pre-fabricated Housing Technology performance by time

- The technology's ability to reduce construction time and can be produced from 4-5 months. But the transportation cost to the assembling site could be bit elongated than expected because of road condition.

Pre-fabricated Housing Technology performance by Cost

- Pre-fabricated Housing Technology presents a balance between higher initial costs and lower overall costs due to efficient production processes.

Pre-fabricated Housing Technology performance by Quality

- Pre-fabricated housing technology in streamlining construction processes and enhancing sustainability depends on the manufacturing industry or factory.

Concrete and Qacha Housing Technology

Loza and Birhanu plc. Working on providing private rental houses with a low-cost design and building Technology (Concrete and Qacha Housing Technology) which is the invention of Mr. Birhanu kasa, a civil engineer by profession and have more than 20 years of experience in the field of construction and consultancy. The built a areas include site in Ayer tena,Kolfe,Aware and Asko.

The land acquisition process is unique on this specific project and the model gives additional and new strategy for private a developer who needs land to implement their projects. The strategy is part of a solution when the proposal submitted there was a letter of request for a plot to develop but the bureaucracy and the process acquiring the land makes very difficult and time taking. at the meantime the project needs to qualified and tested by Ethiopia quality assurance office which helped the developer implement the project so the developer come up with the new idea of acquiring plot from private landlord to develop that was open or vacant lands in private land lords compound the 38 construction system let parts of the housing elements to be move to a different area because these houses are not only mounted to stay in one place permanently. The land acquisition process had two options these are: Option one Stated that if the landlord only let to rent the vacant plot for the period of three years.

Furthermore, the landlord didn't own the houses after the end of the agreement and the developer had full right to take all the parts of the building by disassembling the housing units at the end of the agreement period. In this case the landlord only gets money from the rent of vacant plot in the compound for the period of three years only. Option two is the landlord should sign the agreement for the period of five years. and the difference between option one and two is; one, the agreement period extended by two years, second after the end of the third year of the agreement the landlord was beneficiary from the houses and get 50% of the rent cost collected from the tenants in addition to that of the vacant plot rent for the next two years until the end of five-year agreement, third, at the end of the agreement which is the five years agreement period the land lord could own the houses and rent for tenants

with a new landlord and tenant agreement. The developer should not engage in any form without the consent of the landlord after the end of five-year agreement.

The technology

The innovation had a vision to solve the problem of housing in simple construction system which is very cost wise compare to traditional construction system and method and focused to address different type of housing scheme which can deliver and solve the problem of housing shortage in the city of Addis Ababa.

Performance Indicators:

- cost-efficient
- Both more and less time required
- Strong & Durable, depending on the skill of builders and structural design

Concrete and performance by time

- Concrete and Qacha Housing Technology is often more expensive to construct initially because of building material fluctuation from time to time and labor costs. its durability once made and low maintenance needs make it cost-effective over the long term.

Concrete and Qacha Housing Technology performance by Cost

- While it can be both expensive and cost-efficient depending on the context, the difficult aspect on this project is access to finance because of the new development scheme and approach of construction. Either the government side or the private financial institution was not committed to fund the project. But the reason behind the financial institute not to let loan was the legal certification issue of the development that takes long process from government side and the complication is to have this legal certification the government need to see the pilot project with full package such as with tenant occupation and service. According to the developer to implement this project the only option was to shift all the assets of former construction

company that owned by the developer and resolve the finance issue and take a risk. According to the developer interview the data analyzed by the office indicate that the market is full of low-income tenants who can't afford to rent from a private landlord in the informal renting market. even the studio type house in informal private renting market rent price start from 4000birr – 6500 birr in average but the price that the developer offers and the size of the house was very perfect for the tenants with respect to their financial capacity. Moreover, the project idea behind building those houses and selecting the target groups or offering this house for low-income tenants was set as a goal but on the process of implementation to achieve the goal there was no written rules and regulations or criteria to select low-income tenant groups but simple conversation with tenants and according to the brokers suggestion tenants will get the opportunity to rent those houses.

Concrete and Qacha Housing Technology performance by Quality

- The construction was not the same and typical with the current construction system implemented these days in our country starting from constructing the sub structural part of the building to the upper structures. The sub structure parts especially the foundation details is eliminated and replaced by a 'U' shaped element and simple construction method which is part of the uniqueness of the project. The construction has mainly three phases: phase one is site clearing and layout preparation, phase two assembling parts of the building and phase there is roof and finishing works. The technology is durable and strong, which are contingent upon the skill of the builders and the structural design.

Figure 12: manufacturing process

Source:https://youtu.be/q772Ci26yY?list=PLCjJqBmiqEtWbv8j0MgUi_nD6GFyAbt0i&t=797

Figure 13: Middle of Building House with Qacha and Concrete

Source: - https://youtu.be/RGLcGnlXPkU?t=52

Figure 14: Final outputs

Source:-Researchers own photo

Mud Block Housing Technology

Gemech and Friends plc. Working on providing Mud block design and building Technology) which is in to business for more than 10+ years of experience in the field of construction. The built areas include site in Adama ,Oromiya.

The technology

The technology has been in to practice for over 50 Years especially in hot areas. The Private Plc. mud block developer states that. Mud block can be developed from earth materials which offer mixture of soil, sand, clay, and sometimes straw or other binding materials is used to create the blocks. The mixture is then packed down into molds to form blocks of various sizes. Once shaped, the blocks are left to dry and cure for a certain period before being used in construction. The blocks are laid in courses with mortar or mud plaster between them. The walls can be reinforced with bamboo, steel bars, or other materials, depending on the design and local conditions.

Performance Indicators:

- Low cost
- Varying construction time because of weather condition
- Good thermal properties and environmentally friendly

Mud Block Housing Technology performance by Quality

- Mud Block Housing Technology stands out for its very low cost, varying construction time depending labor cost, good thermal properties for very hot area but have very high load because of that the technology can only be built in G+ 0 floors. Mud block housing technology can providing affordable and ecologically friendly housing solutions.

Mud Block Housing Technology performance by Time

- Construction time for mud block housing may be longer compared to other technologies Because of drying of the blocks and cubes must be in consideration.

Mud Block Housing Technology performance by Cost

- Mud block housing can be cost-effective due to the availability of local materials. Can provide long-term cost savings through low maintenance requirements.

Figure 15: Mud Block house in construction Process

Source: https://lens.usercontent.google.com/image?vsrid=CMOcuenZ-Sounc

4.2.2 Gaps of application of 3D printing technology

3D Housing Technology

The Federal Housing Corporation, in its recent efforts to introduce advanced construction technology into the country, has entered into an agreement with Baumit Group, a major Austrian construction technology provider. The Corporation's Chief Executive Officer met with senior officials from the construction technology provider in Wopfing, Austria, and discussed the practical implementation of 3D construction printing for the Federal Housing Corporation.

Following the recent agreement, the 3D construction printing technology is expected to become the third modern construction technology that the Corporation will introduce to Ethiopia's construction industry. the size of the proposed machine is 2m*1.5 m*1.5 m.

Figure 16: Machinery sample made in Ethiopia

Source- https://web/photo?fbid=1087368133436412&set=pcb.1087369003436325

3D construction printing has been widely adopted in Europe and Asian countries in recent years, and its effectiveness has been proven in African nations like Rwanda and Kenya.

The agreement is made with Austrian Baumit Group is expected to play a significant role in meeting the growing demand for modern construction technologies in Ethiopia and addressing gaps in technological supply within the construction sector.

It has been noted that 3D construction printing technology reduces construction costs by more than half compared to traditional methods and enables the realization of complex architectural house designs.

The technology uses 98 percent locally sourced materials and can complete large-scale housing projects and construction works within months. It is also capable of constructing villa-type residential buildings in less than a day. Given Ethiopia's high population density in cities like Addis Ababa and other urban centers, the ability of 3D construction printing to deliver housing quickly, affordably, and with quality makes it a potential game-changer in addressing Ethiopia's housing supply challenges.

Participation in "Bauma 2025" international exhibition held in Munich, Germany global exhibitions, the Federal Housing Corporation has engaged in discussions with several leading international organizations considering a premier platform showcasing cutting-edge, cost-effective, and high-quality construction inputs, machinery, and technologies from around the globe gaining valuable insights for future projects. Baumit Group provides direct support to the Corporation in the effort to bring this technology to Ethiopia and will collaborate closely on its implementation.

The adoption of 3D concrete printing the technology still faces major technical barriers that limit its readiness for widespread housing construction. Key among these is the need for extensive research into printable concrete material properties, particularly mix designs that ensure adequate flowability, workability and structural integrity under local environmental conditions. Moreover, integrating traditional

reinforcement within 3D-printed elements remains a critical challenge, especially for load-bearing and multi-story structures. Without reliable solutions for reinforcement, durability, and long-term performance, the structural safety of 3D-printed housing cannot be fully ensured. Advancing this technology requires strong collaboration between research institutions, engineers, and policy-makers to develop context-specific materials, design codes, and hybrid construction methods because noting has been made it to Adaption.

4.3 The supply process failure management System

The processes, regulations, and technical advancements intended to detect, resolve, and avert malfunctions in housing provision systems are together referred to as the housing supply process failure management system. These mechanisms are essential for handling the different issues that emerge in housing markets and guaranteeing a sufficient, reasonably priced, and high-quality supply of homes.

4.3.1 The existing management practice and enabled technology

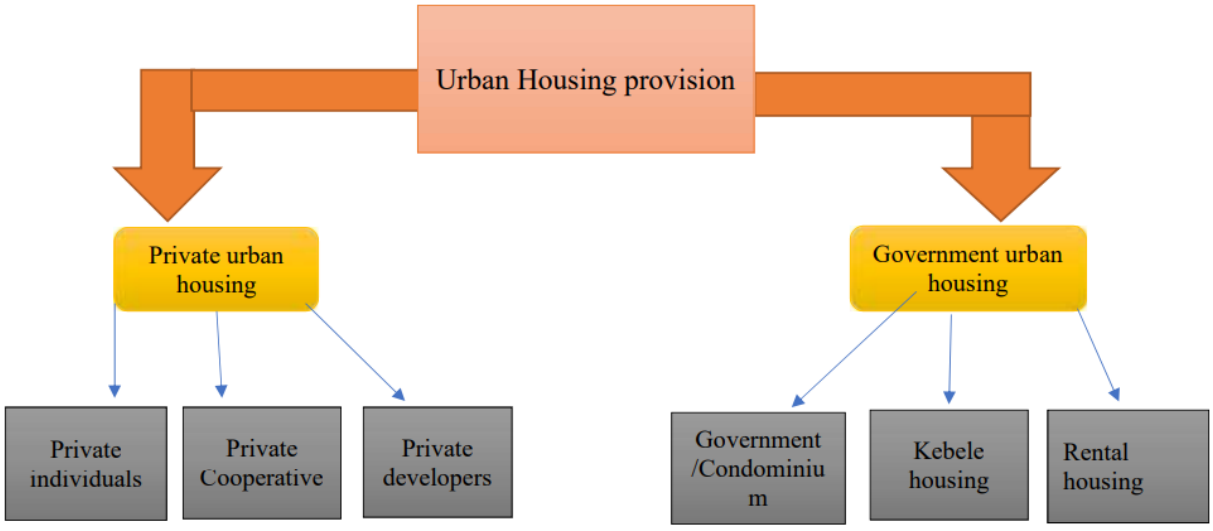

Figure 17: Existing Housing Management Housing Provision

Formal Urban Housing Provision

The formal urban housing supply is 69.8%, according to a survey done in 27 Ethiopianmunicipal administrations (MOUDH, 2015). The greatest provider of urban housing is theInternational Housing Development Program (IHDP), with 51.1 percent; the second highestprovider of urban housing is private individuals' developers (cooperatives and leases), with 22.2percent. Individual and cooperative land development plots supplied by the government has beenhalted, notably in communities implementing the IHDP, which was thought to create prospectsfor more intensive land usage. Finally, municipalities (outside of the IHDP) donated 0.5 percent,and real estate developers gave 0.4 percent.

The institutional supply of urban housing in emerging countries is mostly for the high-income urban inhabitant. This has being accomplishes with private markets. The government provides housing for middle- and low-income urban dwellers, as well as government employees, in either direct or indirect ways. The other type of urban housing is that which has provided cooperatively or independently by governments. Government assistance comes in the form of land, cash assistance, or building materials. However, the government's provision/supply of IHDP urban housing has a difficulty in that the number of urban housings created thus far is insufficient to meet the demand of city people. This issue of completing and transferring housing units to beneficiaries took a long time to resolve. Adding more time to the development process raises the price of urban housing markets and makes them more unaffordable.

Government Urban Housing Provision

Building housing units for essential employees such as technocrats, middle and high managers,security and military personnel, or for lower and middle-income people, governments become involved in housing provision to reinforce the state's demands. This can be accomplished either directly through the introduction of building programs for entire dwelling units or indirectly through assisted self-help and settlement upgrading programs.

Private sector Urban Housing Provision

In emerging countries, formal private sector urban housing provision has been higher for highincome urban dwellers (MOUDH, 2015). As a result, the National Development Policy emphasizes the importance of private real estate development. The private sector's contribution helps to alleviate Addis Ababa's urban housing shortages for people with higher income levels. The private real estate sector has managed to build a significant number of urban residences,although far less than anticipated.For example, in Addis Ababa, between 2000 and 2011, real estate accounted for only 3.8 percentof housing supply, compared to 61.1 percent for the government and 35.1 percent for individuals(cooperative and lease). In the modern urban development process in the metropolis, Ethiopian real estate development is relatively short. However, according to (MOUDH, 2015), the development of real estate with the demand for urban housing programs was quite minor between 2000 and 2011. Some real estate developers are acquiring property to build an urban house in order to provide urban people and alleviate the city's urban housing challenges.However, a number of real estate developers in the city keep idle lands with no progress.

The 70/30 public-private housing management strategies

Developed trough almunium form work private developers building 70% of housing units for sale, while the government receives 30% to allocate to low-income residents. This scheme aims to address the country's growing housing shortage and provide affordable housing options for a wider range of residents.

4.3.2 Gaps of enabling the 3D printing technology

Enabling 3D printing in Addis Ababa faces several key gaps, including awareness which is being created though ministry of urban and infrastructure, construction management institute and the federal housing corporation. Which also a lacks of skilled workforce, limited materials, and potential regulatory and security challenges Additionally, the technology's high initial cost coupled with the need for significant

pre-processing and post-processing, can hinder its widespread adoption, especially for rapid prototyping or small production runs.

- 3D printing in housing needs to have a proper rules and regulation and working conditions to be implemented.
- A shortage of trained professionals in 3D printing, auto cad design, and related fields is a major obstacle.
- Educational institutions need to prioritize the training and re-training of workers to meet the growing demand for 3D printing expertise.
- The selection of materials suitable for 3D printing is not exhaustive, particularly for specialized applications.
- The size of objects that can be printed is often limited by the available 3D printers.
- The cost of 3D printers and associated equipment can be a barrier for small businesses and individuals.
- The need for auto cad modeling, software, and post-processing can add to the overall cost and time investment.
- 3D printing speed can be faster than traditional manufacturing methods, and achieving high accuracy and detail can be challenging.
- The absence of clear regulations and standards for 3D printing can create uncertainty and hinder its widespread adoption.
- Inadequate infrastructure, such as reliable power and internet access, can further complicate the adoption of 3D printing.
- Raising awareness about the capabilities and benefits of 3D printing is crucial for fostering its adoption across various industries.
- Government and private sector initiatives are needed to support education and training programs that develop the skills necessary for 3D printing.

- Encouraging collaboration between academic institutions, research organizations, and industry stakeholders can help foster innovation and address challenges more effectively.
- Investing in research and development to create and utilize locally sourced materials for 3D printing can reduce costs and promote sustainability.
- Clear regulations and standards can help ensure the safety and reliability of 3D-printed products.
- Collaborating with security experts and developing appropriate measures to mitigate potential risks is crucial.

CAPTER FIVE

FINDING AND DISCUSSION

The case study emphasizes the importance of considering factors such as initial costs, long-term savings, construction time, quality of construction, durability, energy efficiency, and environmental impact from each of the under studied technology when choosing alternative housing technologies in regarding Managing housing supply process failure.

When it comes to alternative housing technologies in Ethiopia, several innovative options are available to address the housing supply process failure during the country's urban transition. In this case study as mentioned above, the researcher explores the Concrete hollow blocks (Conventional housing technology), Aluminum Formwork, Prefabricated Technologies, Concrete and Qacha Construction Technologies, Mud Blocks Construction Technologies and the promising 3D housing technology. The findings will be summarized on table

Table 2: Performance of technologies

Technology Type	Performance Indicator		
	Cost	Time	Quality
Aluminum Formwork Technology	High Initial Cost	Reduced Construction Time	precise construction
Pre-fabricated Housing Technology	Higher Initial Cost,	Reduced Construction Time but transporting the panels is time taking	Offer energy-efficient options
Concrete and qacha Housing Technology	Cost efficient	Time requirement depending on man power and	Durable depend on skill builder

		the size of the house	
Mud Block Housing Technology	Low Cost	Varying Construction Time	Good thermal properties but more proper for hot areas
Concrete hollow blocks(Conventional housing technology)technology	Depends on the time of the construction that the material can be bought	Depends on human labor	depend on the construction techniques and the design
3D housing technology	Can be produced with low cost	Significant reduction of time	Durable and sustainable

Aluminum formwork which allocated around gergi is a modern construction technology that uses aluminum panels to form the concrete structure of a building. This technology involves using aluminum panels to construct walls, slabs, columns, and beams in a faster and more efficient manner than traditional construction methods. This technology is known for its speed of construction, as the aluminum formwork system allows for quick assembly and disassembly. However, when it was seen in terms of performance indicator results above the initial costs of using this technology may be higher compared to traditional construction methods, but it can lead to long-term savings due to its efficiency and durability this means that its affordability for the target group of the lower income level citizen of Addis Ababa is questionable. Additionally, the quality of construction using aluminum formwork is typically high, as the system allows for precise measurements and uniformity in the concrete structure. In a current situation, this technology group may not face a problem of failure to provide affordable houses for the lower level citizen as they agree to do so. However unless a proactive approach from the government to

ensure the well-being and safety of lower-level city dwellers as it was stated in 2.9 of this study the possibility of failure in the housing supply process may happen in area such like acquisition and zoning regulations, lack of supportive infrastructure such as water and electricity connections, insufficient access to financing for affordable housing solutions.

Prefabricated Technologies: pre-fabricated technologies which established by ECDSWC offers prefabricated building solutions that are cost-effective and timesaving. As interview made with key informants and stakeholders plus the site visit of the researcher the prefabricated technologies that have lower initial costs due to standardized components and assembly processes, this may lead to savings in labor costs and potential energy efficiency savings over time. The initial costs of prefabricated technologies vary based on the size and complexity of the project but it can be concluded that it tend to be lower than traditional construction methods. As the result of this Prefabricated Technology lead to long-term savings through reduced labor costs, accelerated construction time, and minimal material wastage .the quality and durability of buildings made by prefabricated are typically high, ensuring structural integrity and longevity. Moreover, prefabrication is known for its energy-efficient design and minimal environmental impact. These factors contribute to efficient housing supply management in urban areas.

However, there will be a possibility of failure on managing housing supply process - the technology gap of the management system for urban transition process unless as it was indicated in this study the factors of failure such as Lack of regulatory framework - lack of clear regulations and guidelines; Limited access to financing- Lower-level city dwellers may face challenges in accessing financial support or loans to invest in alternative housing technologies; Infrastructure challenges- specific infrastructure support, such as access to utilities or transportation and Resistance to change - resistance from residents to adopt new technologies.

Concrete and Qacha Construction Technologies: This method of construction offer innovative concrete and Qacha (plant-based construction) technologies for sustainable housing solutions.

As interview made with key informants and site visit on project area the researcher observe that the design and manufacturing parts of the building and assembling process was one of the unique characters that differentiate the project from other housing related projects. This project manufacture parts of the building on site or a precast system with different size and design type this are: one, wall panel a 1 meter by 2-meter (2m x 1m) board with a thickness/ depth of five centimeter (5cm).two, structural wall parts which used as a supportive element that used for structural purpose these are a right-angle element attached with the wall and the other element is a 2m High and a 40 cm width with a depth of 5cm which help as additional structural element for the construction. Lentil type of element, which used as a horizontal structural element that span openings such as the door and widow part of the building Fourth, 'U' shaped foundation element with a depth of 15 cm, 90cm length and 25cm width. This element used as a foundation and grade beam that transmits the load of wall in to the ground.

This technology aim to address the housing supply process failure in Ethiopia by improving construction quality, durability, and energy efficiency the initial costs of adopting concrete and Qacha technologies may be moderate, but they offer long-term savings through reduced maintenance and improved energy efficiency. The construction time for concrete and Qacha technologies is relatively shorter compared to traditional methods, resulting in faster housing delivery. Moreover, the quality of construction using these technologies moderate structural stability and longevity. In terms of environmental impact, concrete and Qacha technologies may have a moderate footprint but can be sustainable with proper management practices.

Developing housing projects currently need huge amount of budgets and commitment from both government side and public sector. Resolving this problem by the technology owners and findings revealed that the government housing provision mechanisms and strategies are very costly and oriented only home ownership approach which is not mainly consider the low-income part of the community and ignore the private rental housing market. It means the Problem of

affordability by the lower level income city dwellers of Addis Ababa is still not getting a solution by this technology because its cost unless government intervention on Lack of regulatory framework, Limited access to financing, Infrastructure challenges and Resistance to change get an improvement.

However, this project come up a new approach called a private rental housing scheme with low price of construction system. When we compare the project with the conventionally constructed houses by different landlords in the informal renting market cost to deliver the same size house needs 1,000,000 ETB to 2,000,000 ETB in current (2025) construction price and by meter square in the informal market it needs 36,000 ETB. Whereas, it becomes expensive with time and has a limitation on building multi story housing.

Mud Block housing Construction Technologies: Based on the interview made with key informants and site visit at project area mud blocks construction technologies involve using locally available materials such as mud, water, and stabilizers to create sustainable and cost-effective housing solutions. The initial costs of mud blocks construction is low, making it a viable option for affordable housing projects. Long-term savings can be achieved through reduced material costs and energy-efficient design. Mud block construction represents a harmonious blend of traditional techniques and modern innovations, offering a sustainable alternative to conventional building practices. However, the construction time for mud blocks technology may be longer than some of the other technologies mentioned but offers a unique approach to housing supply management in urban areas and the quality and durability of mud blocks may not be as durable as other materials, it is susceptible to erosion and water damage proper maintenance can ensure their longevity. Load-Bearing Capacity: Stabilized mud blocks generally offer adequate load-bearing capacity, but the design must be carefully considered.

Therefore, Mud Blocks Construction Technologies as housing technology option fail the performance indicator shown in above in terms of time and quality using in managing housing supply process gaps of urban transition process; the technology

gap of the management system in Addis Ababa which designed to provide to solve housing problem for the lower income level community.

The analysis observation confirmed that 3D printing is not applied by the supply process but is ongoing and yet not enabled by the management system responsible.

The advent of 3D printing technology in Housing has introduced a transformative approach to housing production. As evidenced by projects in the United States and the Netherlands, 3D printing can significantly reduce both construction time and costs while improving the overall quality of housing. This is particularly relevant for countries like Ethiopia, where housing demand is growing rapidly, and affordability remains a major challenge. This research explores 3D printing technologies as an alternative approach to managing housing supply process failures in Ethiopia by examining the factors of time, cost, and quality.

Evaluation of 3D Printing Technology: Time, Cost, and Quality

1. Time:

3D printing in construction significantly reduces the time required to build homes when compared to conventional construction methods. For instance, in the United States, 3D-printed homes can be constructed in just a few days, with some projects taking as little as 24 hours (Sánchez, 2018).Similarly, in the Netherlands, the world's first 3D-printed neighborhood was completed faster than traditional construction projects. In Ethiopia, this time-saving potential could address the growing demand for housing in urban areas, where slow construction timelines often contribute to housing shortages.

Key Benefits:

Reduced construction time for mass housing projects

Faster turnaround for emergency housing needs.

Quick adaptation to changing urbanization patterns

2. Cost:

One of the most significant advantages of 3D printing in construction is its potential to drastically reduce building costs. Traditional housing construction often incurs high labor and material costs, particularly in a developing economy like Ethiopia. However, 3D printing can minimize these costs by reducing labor needs and material waste, as the technology uses precise quantities of material. For example, a 3D-printed home in the United States may cost around $4,000 to $10,000 (Ethiopian Birr 540,000 to 1,350,000) (Sánchez, 2018), significantly lower than traditional methods. In contrast, building a conventional house in Ethiopia can cost between $10,000 to $15,000(Ethiopian Birr 1,350,000 to 2,025,000 including labor and material expenses (World Bank, 2020).

Key Benefits:

Reduction in overall construction costs (material and labor).

Lower housing prices for low-income families.

Potential to streamline procurement and reduce supply chain inefficiencies

3. Quality:

The quality of 3D-printed homes is generally higher than conventional housing in terms of uniformity and structural integrity. 3D printing offers high precision in construction, reducing the likelihood of human error and inconsistencies that can often occur in manual construction. Moreover, advanced materials, such as reinforced concrete and eco-friendly composites, can be used in 3D printing, which could enhance the durability of homes in the long run. This is particularly beneficial in Ethiopia, where harsh weather conditions can take a toll on conventional housing.

Table 3: : Comparison Table

Measurement	Conventional(Traditional) Housing	3D House Printing
Time	Weeks to months (formwork setup delays)	Days to weeks (continuous printing)
Quality	Limited to rectilinear shapes	High (curves, lattices, geometries)
Cost	High cost	Reduces cost by 50% percent

Conventional Construction:

In Ethiopia, the cost of building a low-cost house using traditional methods is per 1 sq. is minimum estimated to be between 20,000 and 35,000 birr including labor, materials, and time while labor is cheaper in Ethiopia compared to developed countries, inefficiencies in construction and material wastage drive up costs.

Estimated Cost of Importing 3D Printing Technology to Ethiopia:

The cost of importing 3D printing technology to Ethiopia involves the following:

- 3D Printing Machines: The cost of commercial-grade 3D printers for construction ranges from 13,500,000 birr to 67,500,000 birr.
- Training and Support: Establishing local training programs and technical support services could add an additional 13,000,000 birr to 20,250,000 birr in the short term.

CHAPTER SIX

CONCLUSION AND RECCOMENDATION

Based on the assessment of managing housing supply process failures related to alternative technology based on performance of cost, time, and quality, the following conclusion and recommendations can be made:

Based on the analysis of managing housing supply process failures related to alternative technology, here are the conclusions and recommendations

6.1 Conclusion

The study highlights how 3D house Printing is growing quickly and gaining popularity, as seen by notable advancements .The steady increase in academic articles over the last 10 years is indicative of the growing interest of specialists and researchers in developing 3D printing technology. This transformative construction technique has been developed with the help of leading countries. Notable contributions have come from countries like China, the Netherlands, and Germany. International collaborations further confirm the rising interest and development within the 3D Printing field.

The integration of 3D printing technologies presents a compelling alternative for managing housing supply processes failure in Ethiopia. The technology offers significant benefits in terms of reducing construction time, lowering costs, and improving quality of housing, which are critical to solving the housing crisis in Ethiopia. However, challenges related to high initial investment, lack of technical expertise, and regulatory hurdles need to be addressed to fully realize its potential. The management system has opportunity to enable 3D printing technology for managing the housing supply failure but the opportunity is not exploited mainly because of awareness created and proper regulatory frame work for implementation of the technology.

To overcome these challenges, on March 2025 it is seen that Addis Ababa federal housing corporation engages in partnerships with germen international technology companies and experts in 3D printing to pilot projects. This approach can facilitate the adoption of 3D printing technology, improve the affordability and sustainability of

housing, and create a skilled workforce that can lead to long-term success in addressing Ethiopia's housing supply issues.

6.2 Recommendations

As a recommendation, based on the study results, it is evident that there are significant challenges hindering the effective implementation of alternative technologies in managing housing supply in Ethiopia. To address these issues, it is recommended that policymakers, urban planners, and stakeholders collaborate to establish clear regulations, standards, and oversight mechanisms for the adoption of 3D printing housing technology in the housing sector. Providing financial incentives and sample adaption programs can help incentivize the use of 3D printing housing technology. It will a key in overcoming cost overruns, delays, and compromised quality. By prioritizing these measures, it is possible to improve the efficiency and quality of housing supply management in Addis Ababa and contribute to sustainable urban development in Ethiopia.

The introduction of 3D printing technologies in Addis Ababa could play a pivotal role in addressing the country's growing housing demand, particularly for low-income families. With reduced construction times, lower costs, and improved quality, 3D printing represents a promising solution to the challenges faced by housing sector. However, to fully capitalize on this technology, the management system must overcome significant barriers, including high initial investment costs, the need for technical expertise, and regulatory adjustments. Through partnerships with tech companies and targeted investments in training and infrastructure, Ethiopia can harness the potential of 3D printing to revolutionize its housing supply processes.

Based on potential benefits of 3D printing technology in construction, it is possible to reduce house prices by up to 50%, shorten project durations by 70%, and improve the overall quality of building projects with the introduction of 3D printed houses in other country experience. Therefore, the following recommendations are proposed for its implementation in Ethiopia:

1. **Conduct Detailed Cost Analysis**: by gather local data**,** initiate research to collect specific cost data related to 3D printing technology in the Ethiopian context. This should include material costs, labor, and operational expenses to better understand the financial implications.
2. **Pilot Projects**: Implement pilot projects to construct 3D printed houses, focusing on typical Ethiopian housing designs. These projects will provide valuable insights into the practicalities and cost-effectiveness of this technology.
3. **Collaborate with Local Stakeholders**: Collaborate with government agencies, construction firms, and technology providers to facilitate knowledge sharing and support the integration of 3D printing in the housing sector.
4. **Develop Training Programs**: Establish training programs for local builders and technicians to equip them with the necessary skills to operate and maintain 3D printing technology effectively.
5. **Regulatory Framework**: Work with regulatory bodies to develop standards and guidelines for the use of 3D printing in construction, ensuring safety and compliance with local building codes.
6. **Explore Material Options**: Investigate the use of locally available materials that can be utilized in 3D printing, potentially reducing costs and enhancing sustainability.
7. **Public Awareness Campaigns**: Launch campaigns to raise awareness about the advantages of 3D printing technology, emphasizing the potential for reducing housing costs by up to 50% and addressing the housing shortage.
8. **Continuous Evaluation**: Establish metrics for evaluating the performance and impact of 3D printed houses, using this data to refine future projects and strategies.

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ANNEX I

Publishable Manuscript

Managing the housing supply process's failures by enabling construction technologies: Possible housing solutions using 3D printing technology in Addis Ababa

Melat Teklegiorgis and Dr Heyaw Terefe

Abstract

Housing supply failure is a global phenomenon which has affected close to 1billion people across the world. One of the instruments by which the failure is attempted to be managed is improved construction technology which has currently reached producing the houses by using a robotic technology. The literature indicate that the technology is rapidly evolving and that it offers advantages over traditional construction methods, including increased speed/ time, cost savings, and design flexibility.

Ethiopia has a huge housing supply gap. Moreover, it has a very high population growth rate indicating its population is projected to double in the next 30 years to reach 210 million. The objective of the research was to investigate the extent to which enabling the 3D technology has been considered in managing the housing supply failure in Addis Ababa, the capital. A case study method including interview, document review, and focus group discussion was used for the research.

The findings indicate that, the management of the housing supply process's failures is reliant on "traditional" construction technologies; the modular construction technology is limited to the type transferred in the 1980s, and that there is no practice of enabling the 3D construction printing technology although it has the potential for addressing the failure.

1. Introduction

The research is based on the observation that studies on the management of the housing supply failure by enabling construction technologies in developing country cities like Addis Ababa have the 3D construction printing technology enablement practice gap. The observation is made in the context of the literature on housing and the housing supply system including the demand side, the supply side, and their failure management system. Each context is discussed in short here under.

1.1 Housing

Housing is one of the necessities of life. A basic human need, it offers refuge, safety, and a basis for social interaction. It includes social, economic, and cultural elements in addition to physical structures. Housing transcends physical shelter but determines even social, physical and psychological well-being of man. It has several functions for society and individuals such as besides being a shelter; it provides protection and private space for its users, a social space for the households and a space where social relations with the society are continuously reproduced. It is a complex product that is crucial for national development in terms of both economy and welfare. From the perspective of residences preference and choice according to their financial status housing can be defined as a mass-produced consumer product, human use values must be substituted for material values.

1.2 The Housing Supply System

1.2.1 The Demand Side

Although the UN recognizes access to decent housing as a human right, issues with affordability (Cost), sustainability (Quality), and urbanization continue to exist on a worldwide scale. Housing affordability is not simply a matter of housing costs and household income levels. It is also about a household's ability to obtain housing and then to retain it. It is important that households have sufficient residual income to purchase other necessities after paying their housing costs (Chowdhury, 2013). Housing is considered affordable if expenditure relative to income is reasonable or moderate. Nowadays Housing Affordability is an important term all over the country

Various Countries has various concept and situation on housing affordability and maximum countries are facing severe problem of this. It is necessary to understand the problem and solve it. Countries are now dealing with this problem through adopting housing policies and various steps.

1.2.2 The Supply Side

Housing development and delivery is a critical aspect of provision of shelter. It involves a chain of processes and commitment from site/land acquisition, financing, to construction and final occupation or disposal

Housing Land

Land availability is a fundamental factor affecting housing supply. The accessibility and usability of land for development have significant implications for the pace and scale of housing construction. Shortage of land for the development is caused by the high population, rapid urbanization and poorly conceived policy and regulations (Gopalan, 2014). Similarly (Ugochukwu, 2018) viewed that the inaccessibility to the land caused the reduction of affordable housing provision. Scarcity of available land may contribute to the problem of high land prices, crowded neighborhoods and the squatter settlements.

Land Use Regulations: Zoning laws and land-use regulations heavily influence the availability of land for residential development. (Fischel, 2022) discusses how restrictive zoning practices can limit the supply of land available for housing, leading to increased housing costs and reduced affordability. Regulatory frameworks that restrict density or impose extensive land-use restrictions can inhibit new housing development and contribute to supply shortages.

Urban Expansion and Land Scarcity: As urban populations grow, the competition for land in metropolitan areas intensifies. According to Glaeser, 2021), urban expansion often leads to higher land prices and increased difficulty in acquiring land for new housing projects. Effective land-use planning and strategies for densification are crucial in addressing the challenges of land scarcity.

Brownfield and Greenfield Development: The choice between developing on brown field (previously used) and green field (undeveloped) sites can affect the cost and feasibility of housing projects. Studies by (Crompton, Texas 2005) indicate that while brown field development can mitigate some land-use issues, it often involves higher remediation costs compared to green field development.

Housing Finance

Financial resources are critical to the housing supply process, influencing both the ability of developers to undertake new projects and the affordability of housing for consumers.

Various financing models impact the housing supply, including public funding, private investment, and mixed-financing approaches. The Low-Income Housing Tax Credit (LIHTC) is an example of a successful public-private partnership that has facilitated affordable housing development in the United States (Cunningham, 2014). Innovative financing models, such as community land trusts and real estate investment trusts (REITs), are also explored as mechanisms to enhance housing supply (Clark, 2021).The availability of credit for developers and homebuyers is a significant factor affecting housing supply. Economic downturns and changes in interest rates can influence lending conditions and impact the ability of developers to finance new projects. Chen and Gyourko (2023) highlight how fluctuations in interest rates can affect housing demand and supply by influencing borrowing costs and mortgage affordability. Global material shortages can inflate costs. Local sourcing and alternative materials mitigate this. Government subsidies and incentives can support housing development by reducing costs and encouraging investment. Policies such as tax incentives for developers and subsidies for low-income households can enhance housing affordability and stimulate new construction (Miller & Skidmore, 2020).

Construction Technologies and Techniques

The literature generally classifies construction technologies and techniques into traditional and modern types. The traditional types are those which involve

conventional materials, such as brick, stone, and timber, in a strictly regimented process characterized by a sequential and linear process. They prioritize skilled labor take longer time and use more labor and material (partly because of waste) compared to its modern counterparts. Traditional construction methods were initially cost-effective due to the wide availability of traditional materials and a larger pool of well-trained builders, which is now severely dissipated.

The modern techniques like modular construction and 3D printing significantly reduce construction timelines, offering quicker occupancy and cost savings, which is crucial for meeting the growing demand for timely project delivery. Modular construction reduces on-site labor and material waste, compensating for initial higher costs through efficiency and faster project completion. It involves the off-site manufacturing of building components and their subsequent assembly on-site. This construction technique offers numerous advantages, including reduced construction time, cost efficiency, improved quality control, and sustainability prefabricated housing techniques are known for reducing construction time significantly. According to Gibb (2020), these methods allow for the simultaneous construction of building components off-site and on-site, leading to faster project completion. Modular construction, in particular, can cut construction time by up to 50% compared to traditional methods (Smith, 2021). (Gibb, 2020) report that these methods can lower labor costs and reduce material waste, leading to overall cost savings. However, initial setup and transportation costs can be higher, which is balanced by long-term savings.

The 3D Construction Printing Technology

Three-dimensional-printed houses represent a ground breaking shift in building, and the process is actually not that complicated. Industrial-sized 3D printers build life-sized houses layer by layer, which is commonly referred to as additive manufacturing. These printers follow a pre-designed digital blueprint and dispense a cement-based mixture through a heated nozzle. Then, the mixture is solidified by a concrete dryer before applying the next layer, and this process repeats itself until the design is realized. In terms of materials, there’s a variety of options other than

cement, such as polymers, sand, resins, and even sustainable alternatives like bio-resins, and wood composites.

The construction process is autonomous, but human oversight remains crucial to ensure quality control. Specialists must be onsite for complex tasks like plumbing, electrical wiring, and the installation of doors and windows. As for the size of a 3D-printed home, it can span from small prototypes, affordable housing, and luxury homes to whole neighborhoods. Not only does this type of computerized construction reduce waste and labor, but it also solves several pressing issues, such as creating shelters for communities and sustainable housing solutions.

On a more affordable note, Business Insider reports that ICON is capable of producing an economy-sized building, around 600 to 800 square feet, in 24 hours at the low price of $4,000(ETB 540,000). Leading professionals from ICON further highlight that while 3D printing in construction shows promise for cost reduction, the current savings are modest around 10 to 50 percent compared to traditional methods.

The United Arab Emirates is making strides with ICON Technologies, the company behind the world's largest 3D-printed building in Dubai. The UAE is heavily investing in 3D printing technology, aiming to have 25% of all new buildings constructed using this method by 2030.

The cost of a 3D house printer can vary, ranging from a few thousand to hundreds of thousands of dollars. COBOD reports that some 3D house printers are as big as construction equipment with prices reaching in $220,000 (Ethiopian birr 29,704,400). However, smaller-scale printers for construction parts can be found for $3,010-3,207 (Ethiopian Birr 406,410.2- 433,009.14).while specialized concrete printers can range from $10,000 to $20,000 (Ethiopian Birr 1,350,500-2,701,000)

1.2.3 The Supply Process's Failure Management System

Mainstream housing supply process's failure management strategies are dominated by housing subsidies, public or social housing, and housing societies. Housing

subsidies are financial assistance programs aimed at making housing more affordable for low-income individuals and families. These subsidies can take various forms, including rent subsidies, home purchase subsidies, or subsidies to lower housing construction costs. Public housing, also known as social housing, is a type of affordable housing provided by government or non-profit organizations. It is typically offered to individuals or families who cannot afford market-rate housing and often includes rent subsidies or affordable mortgages. A housing society, also known as a housing cooperative, is a legal entity that owns real estate consisting of one or more residential buildings. It's a form of housing tenure where the residents collectively own and manage the property, often as shareholders or members. These societies operate on principles of mutual help, equality, and shared responsibility

In developing countries strategies like self-help approaches, sites and services, and enablement are more common. The Self-help approach was common during the 1970s-mid 1980s. Site and services is a strategy used to address housing shortages, by providing affordable, serviced plots of land to low-income households. Instead of offering fully built homes, governments or developers offer a "site" (a plot of land) and basic "services" (infrastructure like roads, water supply, sewage, and electricity). Families are then responsible for constructing their own homes at their own pace. Similarly cooperatives have got attention through the facilitation of developed land, standard typologies, etc. Protecting the construction of illegal houses or those does not confirm to the standard and plan has got emphasis in the policy.

The enabling approach of the late 1980s-early1990s was characterized by the withdrawing of governments from the direct provision of housing and focusing on establishing legal and institutional frameworks that create conducive grounds to facilitate the efforts of others (the supply process) and enable them to mobilize their full potentials and resources. Some of these enabling schemes are: governments reduced policies and regulations that impede the production of housings, preparing incentives that invite and attract different actors to engage in housing production.

(Bekele, 2003). The approach also laid partnership as a fundamental element for the success of the strategy (UN HABITAT, 2005) It stress on new partnerships to be developed between different actors in the housing development process: governments, the private sector, NGOs and community based organizations (CBOs) and the people/household themselves to maximize efficiency. Under the concept of partnership the approach also intends to engage the private sector and encourages reliance on market actors for housing production. (UNCHS(Habitat), 2001)This addresses one of the basic drawbacks of the previous strategies, reliability. Under the concept of partnership the approach also aim at promoting self-administered CBO as one of the major actors.

2. Research Methodology

The study objective of investigating the practice of managing the housing supply failure in Addis Ababa requires mixed data types by using mixed data collection methods. Therefore, a case study approach which has the potential to accommodate the diversities is used. Thus the data types and the collection methods are as shown in the table below.

Table1: Data collection and Data Type

Data Type	Data Source	Data Collection Method
Housing supply failure	Documents	Review
Housing supply process' applied technologies	Housing suppliers Documents Technologies	Document review Interview/Focus group discussion observation
The supply process's failure management system	Documents People	Review Interview

The technology component of the data sources are selected by using criteria such as ongoing operation and mass housing target.

Data Analysis

Data were analyzed by classifying them under themes of elements of the housing supply system such as the supply side and its failures, and the failure's management system. The thematic areas are provided in the table below:

Table 2: Analytical frame work

Data type		Analytical Framework
Housing supply failure		Cost
		Time
		Quality
Housing supply process	Concrete hollow blocks, Aluminum Formwork, Pre-fabricated Housing, Concrete and Qacha Housing Technology, Mud Block (Adobe blocks) and 3D Housing Technology (Applied Technologies)	Cost
		Time
		Quality
	Gaps of application of 3D printing technologies	Awareness gap
		Feasibility study gap
		Study result gap
		Result implementation gap
The supply process failure management system	The existing management practice	scope
		strategy
		Instrument and enabled technologies
	Gaps of enabling the 3D printing technologies	Awareness gap
		Feasibility study gap
		Study result gap
		Result implementation gap

3. The Case Study: the Housing Supply System in Addis Ababa

3.1 The Demand Side

Ethiopia is one of the least urbanized countries of Sub-Saharan Africa. However, uncontrolled urbanization is a highly visible problem of contemporary Ethiopia. According to (McLeod, 2004) today about 17 percent of the Ethiopian citizens reside in urban areas, principally in the capital city of Addis Ababa. This city is one of the fastest urbanizing ones which mean that a rapid urban growth is occurring in Ethiopia. Unfortunately Ethiopia is a country with very small resources to meet the basic needs of the population in urban areas, (Aseffa, 2002). The flow of people from the countryside to the cities is accentuated in Addis Ababa. However, urbanization is a reality also in minor towns. An uncontrolled flow of people from the countryside into the towns will very often result in deficient housing conditions.

The need for housing is among the top problems in urban areas and urbanization coupled with poor economy has made it difficult to solve the problem. 70% of Ethiopia's urban housing stock does not follow to UN Habitat standards for spaciousness, durability, and tenure security. A large portion of the city's housing is made up of dilapidated, subpar Kebele flats that were built during the socialist era using wood and mud and are in dire need of renovation. One-third of all homes are in informal settlements, which usually lack adequate infrastructure and basic services. The private rental sector primarily provides subpar lodging, with tenants dealing with overcrowding, inadequate upkeep, and unstable lease terms. These problems with quality put residents' health and safety at risk while also not giving them the stability they need to grow economically. Addis Ababa's housing crisis is first evident in the staggering gap between demand and supply. Projections indicate Ethiopia will need 486,000 urban housing units per year from 2025-2035, with Addis Ababa bearing a disproportionate share of this demand. This chronic undersupply creates intense competition for housing, driving up costs and encouraging substandard construction as desperate residents accept whatever shelter they can find. So this is where technology comes in line for better, faster and modern housing.

3.2 The supply side

To address this throughout the period of history there have been different housing development approaches and innovations. Formal private sector urban housing provision has been higher for high income urban dwellers (MOUDH, 2015). As a result, the National Development Policy emphasizes the importance of private real estate development. The private sector's contribution helps to alleviate Addis Ababa's urban housing shortages for people with higher income levels. The private real estate sector has managed to build a significant number of urban residences, although far less than anticipated. For example, in Addis Ababa, between 2000 and 2011, real estate accounted for only 3.8 percent of housing supply, compared to 61.1 percent for the government and 35.1 percent for individuals (cooperative and lease). In the modern urban development process in the metropolis, Ethiopian real estate development is relatively short. However, according to (MUDH, 2015), the development of real estate with the demand for urban housing programs was quite minor between 2000 and 2011. Some real estate developers are acquiring property to build an urban house in order to provide urban people and alleviate the city's urban housing challenges. However, a number of real estate developers in the city keep idle lands with no progress.

Housing Finance

Cost represents perhaps the most significant barrier to adequate housing in Addis Ababa: Conventional housing options, including IHDP units and private sector developers, require a 20% down payment and high monthly mortgage payments that are unaffordable for the bottom 40% of income earners. Many residents spend over 30% of their income on housing, with some paying more than their entire monthly income just on rent. The private rental market features speculative pricing with the provision of new technologies and frequent unjustified rent increases, with landlords exploiting the housing shortage even government-subsidized Kebele housing, while cheaper than market rates, remains inaccessible to many recent migrants due to long-term occupancy

The majority of housing is financed by unofficial sources like savings groups and family, with only 23% coming from mortgages. Issues with urban government are delayed, especially when it comes to infrastructure and land provision. Private developers who may help meet demand have been overlooked in favor of government programs in housing policies.

Construction Technologies

Housing construction, in the formal sector itself, is dominated by traditional technologies like concrete hollow blocks, sisal reinforced concrete, mud blocks, in situ reinforced concrete, etc. A modular construction system introduced in the 1980s was ineffective for many years until it was reactivated during the past five years. An Aluminum Formwork Technology introduced by a real estate company in 2013 which is based on imported modular panels have the advantages of being lightweight, durable, and easy to handle they have high initial cost with cost savings in the long term, Reduced construction time significantly offers potential long-term savings as it allows faster construction, reducing labor costs over time.

The supply process has very limited consideration of the 3D construction printing technology. Only the Federal Housing Corporation has taken some steps in this direction. The steps include: entering into an agreement with Baumit Group, a major Austrian construction technology provider the 3D construction printing technology and providing a sample of the technology in the figure below.

Figure 18: Machinery sample made in Ethiopia

Source- https://web/photo?fbid=1087368133436412&set=pcb.1087369003436325

2.3 The Housing Supply Process's Failure Management System

The housing supply process's failure management system is highly housing strategies oriented. They include the sites and services and housing cooperatives of the socialist period, the condominium, IHDP strategies until the early 21st century, and the current PPP approaches. Major technology based management approach is limited to transfer of the modular technology in the 1980s. There is no data on enabling the supply process to acquire the 3D construction technology by the management system.

4.3.3 The existing management practice and enabled technology

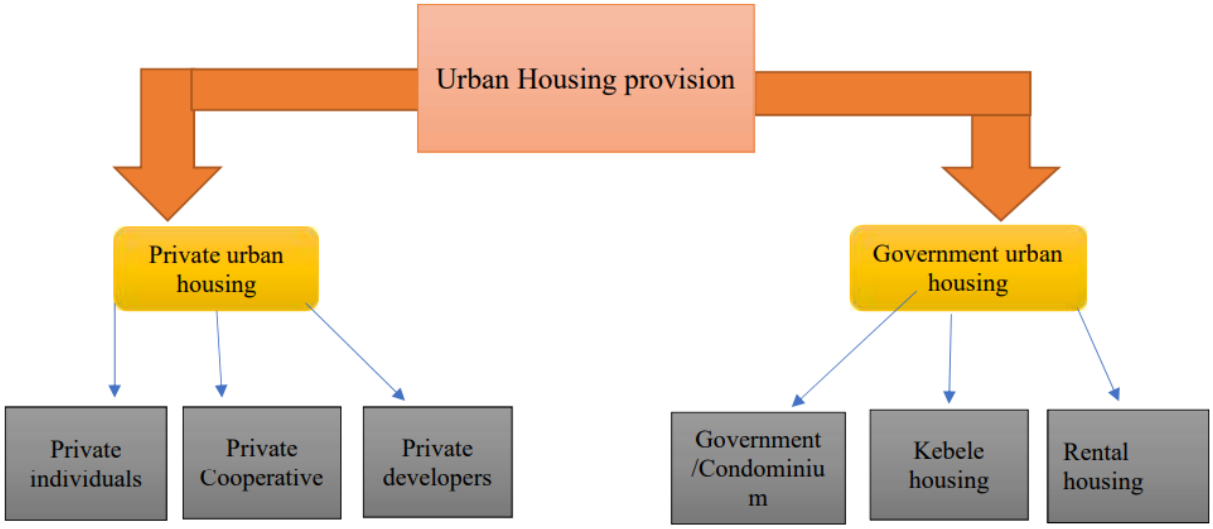

Figure 19 Existing Housing Management Housing Provision

3. Finding, Conclusion, and Recommendation

The study indicates that, the management of the housing supply process's failures is reliant on "traditional" construction technologies; the modular construction technology is limited to the type transferred in the 1980s, and that there is no practice of enabling the 3D construction printing technology although it has the potential for addressing the failure.

The management of the housing supply process's failure in Addis Ababa is mainly focused on housing strategies such as the condominium and the 70:30 PPP approaches. The strategies are based on technologies that can be included in the traditional types although their structures are reinforced concrete. A modular construction system introduced in the 1980s remained ineffective for many years. There is no practice of enabling the 3D construction printing technology even though the literature indicates its potentials for managing the failure significantly.

In Ethiopia, the cost of building a low-cost house using traditional methods is per 1 sq. is minimum estimated to be between 20,000 and 35,000 birr including labor, materials, and time while labor is cheaper in Ethiopia compared to developed countries, inefficiencies in construction and material wastage drive up costs. On the other hand the literature indicates that the cost of 3D construction printing involves:

1. The cost of commercial grade 3D printing machines: Ethiopian birr 13,505,000-67,525,000.
2. Material cost: Ethiopian Birr 6,750 - 27,000 per meter square, depending on the material used.
3. Training and Support cost establishing local training programs and technical support services could add an additional cost in Ethiopian birr 13,500,000
4. The total cost for importing the technology and setting up operations could be around Ethiopian birr 27,005,000 to 81,025,000.
5. Traditional construction technology cost: Birr 36,000birr / square meter and that 3D printed house cost minimum 6,740.5 birr Square meter, a 53.4% cost reduction

Therefore, the study indicates the 3D construction printing technology can be recommended for managing the housing supply process's failure in Addis Ababa. The recommendation includes conducting detail cost analysis, conducting awareness campaigns, and developing standards and regulatory framework for the technology.

ANNEX Ⅱ

ADDIS ABABA UNIVERSITY

ETHIOPIAN INSTITUTE OF ARCHITECTURE, BUILDING CONSTRUCTION AND CITY DEVELOPMENT (EIABC)

POST GRADUATE IN HOUSING AND SUSTAINABLE DEVELOPMENT

Dear Respondent,

I am writing to request your participation in a research study focused on the "**MANAGING THE HOUSING SUPPLY PROCESS'S FAILURE IN ETHIOPA'S URBAN TRANSITION PROCESS: THE 3D CONSTRUCTION PRINTING TECNOLOGY ENABLING GAP IN ADDIS ABABA"** You're for the partial fulfillment of the requirement of master's degree in "Housing and sustainable development" from Addis Ababa University. So, I politely ask you to give me clear information on what you are asked below.

Thank you for considering this request, and I look forward to receiving your valuable input.

Sincerely,

Melat Teklegiorgis

ANNEX II

01 - Interview Questions for private alternative housing technology providers:

Name and your department _____

Your position _____

Your total work experience

a. How do you ensure cost-efficiency in your housing technology solutions?
b. Can you discuss a situation where the housing supply process failed due to cost issues, and how did you resolve it?
c. How do you manage time constraints in delivering housing projects to citizens?
d. What measures do you take to maintain quality standards in the housing technologies you provide?
e. How do you collaborate with government officials to address issues related to housing supply failures?
f. How are you currently managing costs to ensure affordability for citizens when developing housing solutions?
g. Can you discuss any strategies in place to mitigate delays in project timelines that could impact the availability of housing for those in need?
h. What measures are in place to maintain quality standards in affordable housing projects, especially for marginalized communities?
i. How does your company ensure cost-effective solutions for lower-level citizens in need of affordable housing?
j. What strategies do you have in place to streamline the house supply process and reduce implementation time for projects catering to lower-level citizens?
k. How do you ensure that your housing technology solutions remain affordable for lower-level citizens in terms of cost?
l. How do you address potential failures in the supply process that may impact the affordability of housing for lower-level citizens?

ANNEX III

02-Interview Questions for government officials:

Name and your department _____

Your position _____

Your total work experience

a. What strategies does the government have in place to ensure affordable housing for lower-level citizens?
b. How does the government monitor and control costs in housing projects to prevent supply process failures?
c. How does the government enforce quality standards in housing projects to ensure the well-being of lower-level citizens?
d. In your opinion, what role do private alternative housing technology providers play in overcoming challenges in the housing supply process?
e. How does the government collaborate with private alternative housing technology providers to address cost constraints and provide affordable housing solutions?
f. In your opinion, what are the key factors contributing to delays in the house supply process and how does the government plan to address these issues?
g. How does the government evaluate the affordability of housing projects for lower-level citizens in terms of cost, time, and quality?
h. What measures is the government taking to incentivize private alternative housing technology providers to prioritize affordable housing solutions for lower-income communities?
i. What measures does the government have in place to monitor and ensure the timely delivery of housing projects without sacrificing quality?
j. How does the government collaborate with private alternative housing technology providers to address failures in the supply process that may affect the affordability of housing for lower-level citizens?

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