ADDIS ABABA UNIVERSITY

ETHIOPIAN INSTITUTE OF ARCHITECTURE, BUILDING CONSTRUCTION AND CITY DEVELOPMENT

INDUSTRIALIZED BUILDING SYSTEM FOR PROVISION OF MASS HOUSES:

Critical Success Factors and Potential Advantages in the case of Precast Concrete System in Addis Ababa

HENOK SIME

Advisor:
Denamo Addissie, (PhD)

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This research is submitted by Henok Sime in Partial Fulfillment of the Requirements for the Degree of Master of Science in Construction Management from Addis Ababa University, Ethiopian Institute of Architecture, Building Construction and City Development (EiABC).

Denamo A. Nuramo, (PhD)	________________	______________
Advisor	Signature	Date
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Internal Examiner	Signature	Date
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Internal Examiner	Signature	Date

ABSTRACT

Industrialized Building System is defined as a construction method and development approach in which components are fabricated on or off site, transported, and assembled with minimal additional work on site. Industrialized Building System (IBS) is an engineering innovation to prevent most compelling impediments of ordinary strategies of development in order to boost project performance. The system has a significant potential that can be harnessed if utilized for projects like mass housing. An in-depth understanding of IBS and investigating those success factors is inevitably very important prior to adopting IBS technique as a construction technique Addis Ababa where delivering housing is one of the most critical performances challenges for city administration and one of the top priorities for the city residents.

Responding to the challenge and in recognition to the potential advantages of IBS construction technique, the research presents ranked list of potential advantages of IBS construction technique and prioritized rank of critical success factors that affect a successful implementation for mass housing project in terms of their influence on implementation. The first phase of the research cover an in-depth and systematic review of literature resources that produce 8 critical success factors that directly influences implementation and further expanded into 31 sub-factors, further 5 potential advantages of IBS were identified.Survey research methodology used in second phase of the research where questionnaires and interview survey study is carried out and Analytic Hierarchy Process analysis method is used to prioritize identified critical success factors.

The finding rank cost factors first as the most critical factor for IBS implementation followed by knowledge and skill factors. Government policies and regulations factors ranked third, technology factor fourth, supply chain and market factor ranked fifth and management factors at sixth. Production and logistics factors ranked seventh and an integration factor is ranked eighth. Whereas cost efficiency and speed of construction ranked first and second, reduction of waste and quality ranked third and fourth were as construction safety ranked fifth as a potential advantage of IBS. In line with the findings the research recommends the housing construction industry change its conventional on-site approach to IBS construction method, and for a successful implementation respective stakeholders need to play more roles unlocking the critical success factors such as financial incentives, knowledge and skill development and setting regulation and standard to streamline the IBS implementation in housing project life cycle.

KEY WORDS*: Industrialized Building System, Critical Success Factor***,** *Precast Concrete, Mass Housing*

DECLARATION

I declare that this study is my original work towards executing Masters of Science and has not been submitted for any Degree or Diploma in any University. To the best of my information and knowledge, all source of materials used for the study have been duly acknowledged. I have undertaken the study independently with the guidance and support of the research advisor.

SIGNATURE: ______________________

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ACRONYMS

3D	Three Dimensional
AA	Addis Ababa
AHP	Analytic Hierarchy Process
AM	Additive Manufacturing
BIM	Building Information Modeling
CAD	Computer Aided Design
CAM	Computer Aided Manufacturing
CSFs	Critical Success Factors
ECC	Expert Choice Comparison
GDP	Growth Domestic Product
IBS	Industrial Building System
ICT	Information and communication Technology
IoT	Internet of Things
IHDP	Integrated Housing Development Program
MoWUD	Ministry of Works and Urban Development
MSEs	Micro and Small Enterprises
MUDHCo	Ministry of Urban Development, Housing and Construction
PBPPE	Prefabricated Building Parts Production Enterprise
PMC	Prefabrication Method of Construction
UN-HABITAT	United Nations Human Settlements Programme

CHAPTER ONE

1. INTRODUCTION

1.1. General Background

The construction industry by its nature is unique, dynamic, intricate and capital intensive for its realization. The output of construction process can be affected by the technique of construction and technology utilized. The delay in the completion time, cost overrun and poor quality of a construction project are often common problems facing the industry. Development venture is commonly recognized as effective, when it is completed within the scheduled time frame and budgeted cost, by fulfilling the specified quality in the safe manner.

The construction industry in developing countries faces challenges of different kinds, often characterized by time delay, cost overrun and below standard quality construction. In this regard, shortage of residential housing can be cited as a critical issue in major cities of Ethiopia, particularly in urban centers. Major urban centers in Ethiopia are challenged with housing scarcity due to the continually increasing population growth and immigration. Housing inadequacy and affordability is mainly felt at the level of low and middle income and more so with a continuous rise in construction cost at all levels.

In spite of its multidimensional implications universally, access to affordable and housing has been an everlasting challenge (Beer A., 2007). From slum tenants within the third world cities to middle-income family worldwide, millions of individuals are challenged to discover reasonable housing without budgetary constraint. Rapid urbanization combined with urban population growth brought a surge in housing demand in numerous urban areas specially in developing nations.

Aiming to address the high demand for housing in urban regions mass housing concept becomes one of a dominant planning, design and construction approach worldwide. With the advent of this concept, the housing construction sector demand an innovative construction method to fast-track the provision of houses.

Given numerous advantages to the built environment of Industrialized building systems (IBS) based on previous studies, including the reduction of onsite greenhouse gas emissions, and the improvement of construction schedule and product quality. However, the extensive demand of pre-project planning and coordination of stakeholders in the sector have altogether hindered the application of this method.

IBS can be characterized in which building components are mass-produced either within the plant or on the manufacturing plant at the construction site with a rigorous quality control, and lesser site activity (Warszawski, 1999).

Diets (2003), described IBS as the comprehensive integration of all subsystems and components into the overall process using industrialized manufacturing, transportation, and assembly processes. IBS is a system that use industrialized production techniques in the manufacturing and assembly of building components. IBS is an integrated manufacturing and building process with a well-organized system for proper management, preparation, and resource control, processes, and deliverables, enhanced by the utilization of highly developed technologies (Diets, 2003).

The system is used for several reasons, including improved build-ability and associated efficiency gains in terms of time, cost, quality, safety, and environmental targets (Hui, 2005). Some of the benefits include;

- Increase in construction productivity
- Reduced program durations for fixing and erection operations
- Cost reductions at every level of the supply chain attributable to mass production
- Reduced on-site skilled manpower requirements due to streamlined work satisfaction
- Greater quality control yielding in more consistent component profiles and dimensions
- Less wastage of materials as a result of fewer defective products
- A safer working environment at prefabrication facilities –
- A reduced risk of site remedial work due to poor weather

Industrialized Building System (IBS) is a term used to describe the combination of building component automation and preassembly. IBS elements are fabricated off-site and require limited on-site work once installed. This translates to shortened project completion times, increased efficiency, less waste, fewer accidents, and lower total construction costs. Since, components are custom-built cost savings happen in projects with a high degree of repeatability because high-quality components may be replicated multiple times, lowering the price per unit.

The advantage of IBS is that projects are delivered faster and with greater quality since components are fabricated in a controlled environment, making quality control easier. Productivity also goes up, reducing project delivery time by half using IBS.”

Ethiopia, due to the high rate of migration, has one of the fastest population growth rates in the world, that result in an increase in the number of urban centers. With rate of urbanization is at 4.5%, the annual growth rate of the urban population could be as high as 5.4% in the coming two decades. Particularly in urban areas, the Ethiopian Central Statistics Agency projects that the urban population will nearly triple from 15.2 million in 2012 to 42.3 million in 2037. With an urbanization rate of

4.5 % per year, 31.1% of the country's population will be living in urban regions by the year 2037 (CSA, 2013).

As the population of Ethiopia's cities grows, so does the demand for affordable housing, particularly in urban and sub-urban areas. Ethiopia's government runs a housing construction program to meet the increasing demand for affordable housing caused by the country's rapid urbanization. Despite the effort, the paramount housing backlog with an unbalanced housing supply compared to the rising demand becomes frustrating for both the government and registered house seekers in Addis Ababa.

In recognition to industrialization and modernization of construction methods for its superior technological efficiency to transform the society, among the steps taken by the government in this direction was the establishment of the Prefabricated Building Parts Production Factory. Ethiopia's government introduced IBS technology thirty years ago in order to address the issue of housing at the time. The first prefabrication plant was established in Ethiopia in 1986ith the assistances former socialist country Yugoslavia. The company called Prefabricated Building Parts Production Enterprise (PBPPE). The goal was to meet the ever-increasing housing demands in the shortest time possible, to alleviate present housing scarcity, and to meet future demand at the time (Bulto, 1998).

The establishment of PBPPE had opened new opportunity to implement various technical and architectural possibilities. The construction of various building using the technology at a time had paved way for similar design and construction solutions to be adopted by private and government projects and the system have been deemed suitable.

Despite the fact that industrialized building systems have advantages over traditional construction methods in terms of cost savings, less reliance on trained labor, quality control, environmental friendliness, and less reliance on weather delays, the utilization of IBS specially for housing project is limited in Addis Ababa. First, there is a lack of awareness of the potential of IBS, which necessitates a shift in the mindset of construction industry players that IBS is far superior to traditional construction in the long run, which is exacerbated by a lack of technical know-how from production to erection and relatively high production costs, and second, there appear to be insufficient push factors and incentives from governments and policymakers to attract private stakeholders to invest in the production of IBS in order to harness the potential advantage of IBS (Birhanu, 2020).

Since IBS often is associated with sustainable construction, which would be characterized by construction system's ability to consider over the duration of its lifetime, while optimizing its economic viability and occupant comfort and safety it necessitates the use of appropriate and cost-effective technologies in house construction.

1.2. Statement of the Problem

Over the last few decades, Addis Ababa's capacity to offer affordable housing has been severely strained by urbanization and unprecedented population growth. The city administration launched the program to alleviate this housing shortage called Integrated Housing Development Program 'condominium housing project' in 2004 as part of its inner-city upgrading development (UN-Habitat, 2017). Despite the efforts, the process of finalizing and transferring housing units to beneficiaries took much longer, demonstrating that development delays have become a significant challenge for integrated housing development program especially in Addis Ababa (Bekele, 2018). The IHDP initially aspired to constructing 400,000 condominium housing units between the year 2006 and 2010 (UN-Habitat, 2011). Of these, a little over 80,000 were built between 2003 and 2010 in Addis Ababa, (MUDHCo, 2014). According to a Ministry of Urban Development and Housing Corporation (2014) report, by September 2014, a total of 96,233 housing units had been constructed Resulting from severe material shortages, a lack of adequate infrastructure, and inadequate construction management, the construction phase's productivity has likely not been as high as expected during the program's implementation thus far, delaying completion by much to a year on some sites. Approximately 50 % of condominium sites are behind schedule (UN-Habitat, 2017).

The current dominant type of housing construction system in Ethiopia is a conventional system, which is incommensurable with rising housing demand, leading to negative ramifications on housing construction such as lengthy development periods, wastages, increased costs, high embedded energy, etc., which all significantly contribute to the challenge of price unaffordability for the low-income section of the population.

In terms of affordability, incorporating the IBS into construction will reduce cost of construction. The precast element can be cast in the factory and the foundation laid on site at the same time. The overall cost of the construction will drop as the construction period lowers. Furthermore, the utilization of steel and scaffolding system formwork on a regular basis would also save cost. As a result, housing projects could be finished on schedule and people would have access to affordable homes if appropriate construction technologies such as IBS were used in the construction sector.

However, its successful realization of IBS has been constrained by varied factors including, limited stakeholder awareness of the benefits of using appropriate IBS, as well as the coordination and fabrication of a substantial number of building elements, has always been one of the most difficult tasks in the implementation of an industrialized building system (Grills, 2013).

Given the city's present housing supply shortages, the housing industry should identify and evaluate all critical success factors impeding the full realization of IBS potentials in order to deliver mass housing successfully and properly, thus meeting stakeholders' aspirations. Thus, there is a need to investigate into the potential advantages of IBS in the housing development sector, as well as to identify and prioritize the critical success factors for IBS implementation in housing development projects, particularly the precast concrete system.

1.3. Research Questions

1. What are the potentials advantages to utilize IBS precast concrete system for the housing construction sector in the context of Addis Ababa?
2. What are the most critical success factors for IBS, precast concrete system implementation for mass housing projects in Addis Ababa?

1.4. Research Objectives

1.4.1. General Objective:

The objectives of this research is to investigate the potential advantages of IBS (precast concrete system) for the provision of mass houses in Addis Ababa and identify and prioritize the critical success factors for its implementation.

1.4.2. Specific Objectives:

1. To identify the potential advantages of IBS precast concrete system for the mass housing construction sector in the context of Addis Ababa.
2. To investigate and prioritize the critical success factors that would enable the utilization of IBS precast concrete system in mass house development projects in Addis Ababa.

1.5. Significance of the Study

The findings of this research are significant for mass house developers and prefabricated construction material manufacturers to examine for existing potential benefits to utilizing prefabrication methods of construction. The implications of this research for practice in IBS projects are to establish a comprehensive and strong working relationship that allows project stakeholders to perform at their best for IBS implementation. This would boost the competency of built environment professionals in executing IBS projects and attract policymakers, private and public entities to the business. The findings of this study show that CSF is more important and influential for IBS implementation success in specific scenarios and conditions. The findings of this research will also be used to identify those CSFs that are critical for the success of IBS for mass house construction.

The findings could also be used to persuade Ethiopia's housing development sector to widely implement IBS to the local construction industry, which would help the sector broke away from the inefficiencies of traditional (conventional) construction techniques, and adopt IBS to IHDP then it would significantly enhance the productivity of construction operation while also addressing the challenges of providing affordable dwellings in Ethiopia's urban and sub-urban areas.

1.6. Scope and Limitation of the Study

Thematically, the study's main goal is to look into the potential advantages as well as critical success factors of employing the IBS precast concrete system in the housing construction sector, especially in the context of mass housing development. Geographically, the study will also be limited to housing construction sector in Addis Ababa. Time constraints hampered further investigation of the economic analysis for city-wide projects to demonstrate the advantages of IBS versus conventional methods, and obtaining data from key stakeholder for further analysis was yet another major limitation during the research process.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Construction Industry, the Global Trend

Construction is a transformative operation that adds value to a client's project by integrating the elements of a building or structure in a particular manner. It also generates revenue for GDP growth, which has a substantial impact on a country's social and economic well-being. Whether it's for the construction of a building or a project like a road or railway, it's fundamentally a technique of assembling units.

Construction is “An economic activity oriented to the development, refurbishment, repair, or extension of fixed assets in the form of buildings, land improvements of an engineering nature, and other constructions as such roads, bridges, dams, and so forth," according to the United Nations Statistics Division (UNEP, 2003). In the domains of architecture and civil engineering, it is a process that entails the construction or assembly of infrastructure. It includes the construction of new structures, as well as expansions and adjustments to existing ones, including site preparation. It also includes the upkeep, repair, and upgrading of these structures. The construction industry plays a significant role in the delivery of infrastructures, one of which is the provision of housing services.

The global construction market accounts for ten percent of global GDP. In addition, the International Council for Research and Innovation in Building and Construction (CIB) estimates that "a dollar spent on construction can create up to three dollars compared to economic activity in other sectors." (UNEP, 2003).

The world's urban areas are evolving at a faster rate than ever before. The construction sector is one of the development sectors that are affected by global trends such as rapid urbanization of global cities and an ever-increasing world population. Every day, around 200,000 people are entering the world's cities, all of whom require affordable housing, as well as social, transit, and utility infrastructure (ECCB, 2015).

The sector is practically under a moral obligation to reform in the face of such challenges. Its transformation will have transformative effects on society as a whole, by significantly reducing construction costs; on the environment, by improving the use of scarce resources or making buildings more eco-efficient over time; and on the economy, by narrowing the global infrastructure gap and boosting socioeconomic development.

The construction industry significantly affects everyone's everyday lives since the built environment does have a tremendous influence on people's quality of life. While most other industries have seen significant changes and reaped the benefits of process and product innovations over the last few decades, the Engineering & Construction sector has been hesitant to fully embrace the latest technological opportunities, and as a result, productivity has barely budged.

The construction industry is among the least digitized sectors, with almost all its processes being repetitive and labor-intensive (Autodesk, 2019). Large projects often extend 20% beyond the original project completion date and are typically up to 80% over budget. Furthermore, the study reveals a pattern of low or non-existent productivity growth, as well as inferior quality and growing construction cost (Agarwal, 2016).

Part of the reason for the construction industry's sluggish adoption of process and technology advancements can be attributed to these limitations. The industry's ongoing fragmentation, inadequate coordination with suppliers and contractors, difficulties in attracting a competent team, and insufficient knowledge transfer from project to project, to name a few, are some of the factors contributing to the industry's underperformance.

If current trends continue, the world's urban population will exceed 6 billion people by 2045, with nearly a quarter of the population living in slums (UNWUP, 2022). As a result, there will be an increase in demand for affordable housing in metropolitan regions where the development process is complicated by space constraints, as well as economic pressures for additional infrastructure and other amenities spending (UN Department of Economic and Social Affairs Population Division, 2014).

2.2. Construction Industry in Ethiopia

The construction industry is a fundamental sector of the economy that affects almost all other sectors by transforming varied resources into the physical, economic, and social infrastructure that is crucial for socioeconomic growth.

The local construction industry in developing countries economy retains the lion's share of market opportunities. The construction industry makes a significant contribution to Ethiopia's economy, as seen by its GDP share. There has been a significant shift in the way construction work is done during the previous few years. This can be seen in the way construction projects are procured and operated, as well as in new technology utilization.

Construction of road infrastructure, real estate developments, and condominium housing projects are only a few examples of notable advances in Ethiopia's sector. According to the 2017 edition of African Economic Outlook, construction activities in Ethiopia accounted for 15.9% of GDP (researchandmarket.com, 2018).

2.3. Mass Housing Challenge in Ethiopia

2.3.1. Urban Housing in Ethiopia

Ethiopia, a country with projected population of more than 105 million people, is one of the world's least urbanized countries, with only 22.8 percent of the urban population, is also one of the countries with a rapid urbanization rate. The average annual rate of urbanization is 4.5 percent, with some metropolitan centers seeing rates as high as 6% (CSA, 2013).

By the end of 2037, the country's population is predicted to have risen to over 136 million people (CSA, 2013). Even assuming a one-to-one household-to-housing-unit ratio, there will be close to 5.1 million new households for which 6.5 million housing units will be required, even without considering for existing housing supply backlogs of 1.8 million nationwide (GBN, 2020). If the future demand for housing units is not addressed, informal settlements and congested slum communities will proliferate.

Because of the ever-growing population in urban area, efficient housing delivery has been challenging for governments to accommodate the expectations of citizens. As a result, housing development regarded as one of the sectors which can be used to alleviate poverty and promote long-term development. (UN-Habitat, 2011).

Based on the NUDSP, (2015) study's projected growth in population, the additional number of housing unit needs until 2025 and 2035 is estimated to be around 3.9 and 9.8 million units, respectively. (NUDSP, 2015).

2.3.2. Mass Housing in Addis Ababa

Addis Ababa, the nation's capital, is home to over 5.2 million residents, accounts for over 22% of the country's urban population with urbanization rate of 4.3% annually (UN, 2022). Along with substantial population migration into cities, has pushed housing demand beyond capacity. The housing industry, which is responsible for supplying housing stock to the city's people, has been under pressure for some time.

The city's with more than 5 million residents the total number of housing units that have to be built until 2027 in Addis Ababa is estimated to be around 1.2 million housing units. (AACPPO, 2017). These figures reflect the city's housing huge housing demand compared to the city residents.

The city's housing supply is particularly crucial for both the city's middle and low-income residents. A range of factors attributed to the city's insufficient housing supply. The first is a scarcity of land, as well as the widely used market-oriented land management system (Tesfaye, 2007).

Addis Ababa is a metropolis with a huge housing shortage and about 75% of its housing stock is made of mud and wood and half of them are more than 20 years old (Abnet G., 2017). Congestion affects 24.8 percent of homes, with more than two people living per each room (the UNHABITAT minimum standard). Nearly 9% of households do not have access to improved sanitation facilities at all, and 51% of households share toilet facilities. In Addis Ababa, over a third of all families do not even have a separate kitchen (Assefa Z. and Newman P., 2014).

Since 2005, the city administration of Addis Ababa has been implementing a major integrated housing development program to address the city's acute housing problem in order to meet the city's massive housing demand meanwhile more than 182,731 apartment units have indeed been constructed and awarded through ten randomized lotteries since IHDP launched in 2005.

Since 2013, more than 900,000 A.A. citizens have signed up for the city's housing program (AACPPO, 2017). In addition to the current housing backlogs, the figure will almost certainly increase significantly if public-owned residences (which account for 46% of the city's total housing stock) that require major maintenance or replacement are added (Abnet G., 2017).

In terms of cost reduction and accessibility, conventional construction methods and techniques have proven ineffective. Despite the fact that this housing program has introduced more affordable and adaptive construction processes and materials, the program is short of meeting the planned 400,000 housing units till 2010.

2.3.3. Mass Housing Construction System in Addis Ababa

Low-cost or affordable building technologies and materials are often crucial in satisfying the ever-increasing need for rapid housing delivery in developing countries, particularly in addressing the housing needs of the low-income population. An attempt to address insufficient housing supply and to improve the lifestyle of poor urban dwellers is primarily focus on the supply of affordable housing units (Donath, 2012). For the past four decades, Ethiopia's government has been involved in the supply of vertical dwelling units known as condominiums, but it has been unable to satisfy the rapidly increasing demand. Addis Ababa City Administration has commenced this with a new strategy to site expansion and renovation (MoUDC, 2012).

Addis Ababa city administration operates a housing development program to meet the significant demand for affordable housing induced by the country's rapid urbanization, particularly among low and middle-income households. The government operated integrated housing development program main goal is to address the housing supply challenges in AA with a construction of affordable low-cost mass housing units. The construction technique used in IHDP project is dominantly a conventional construction technique with cast in-situ concrete for structural members and precast ribbed slab for flooring and masonry hallow concert blocks for external enclosure and internal partition wall. Despite Government efforts, housing units under construction often took longer than planned completion period associated with the method of construction used which is a conventional construction technique, which in turn affect the target to achieve the required level of demand. (Zerayehu S. W., 2015). Projects delay in the IHDP project is linked to poor project schedule planning, late delivery of construction materials, contractor's planning experience, ineffective site monitoring, poor financial resource management (Bekele, 2018). Which also result in project cost overrun that affect Low- and middle-income earners to afford the units.

To overcome those challenges result in delayed housing unit delivery, with a proven potential of IBS, a wide application of IBS for affordable housing development would be a solution to push the boundaries of building component performance and construction method forward.

2.4. Construction Industrialization

Industrialization is a socioeconomic revolution that transforms society into a broader modernization process, in which social transformation and economic development are directly linked to technology innovation. It is an economy's comprehensive organization for the purpose of production (Sullivan, 2003).

Industrialization entails the mass production of a wide range of products, including elements that can be used by a wide number of stakeholders, each with their own goals that are distinct from the producers. Construction industrialization occurred in various European countries, acting independently and for their own objectives, mainly in response to the high need for housing following World War II (Qays, 2009).

The central theme behind construction industrialization is that the traditional building process should be restructured to focus on mass production of components for assembly rather than planning for most, if not all, processes to be completed on the job site. Site production is a feature of traditional construction, in which production takes place at the final location of the product to be developed. Construction industrialization can be viewed as a structural technique of removing or dramatically reducing on-site operations (Koskela, 2003).

Construction industrialization entails the widespread usage of prefabricated factory-finished large-scale elements and the transformation of production into a mechanized and continuous-flowing process of assembling and installing prefabricated assemblies and parts in buildings and structures.

As a result, industrialization is a streamlined process that promotes efficiency and profit. It is the primary trend in scientific and technological advancement in the construction industry. It serves numerous functions, including enhancing labor productivity, replacing human labor with machines, speeding up building, getting new projects into service faster, lowering costs, and improving quality.

Construction industrialization involves the implementation of contemporary industrial production methods in the construction business (Wang, 2010). According to the European Commission, new and innovative materials account for 70% of product innovation across all industries (ECCB, 2015).

2.5. Current Trends in Construction Industrialization

The International Council for Research and Innovation in Building and Construction (CIB) linked industrialization to product standardization, prefabrication, rationalization, modularization, and mass production in its most recent report on industrialized construction, with continuous improvement in efficiency (CIB Report, 2010).

In contrast, industrialization refers to the application of industrial technologies such as automation, standardization, and prefabrication. Industrialization is a part of a greater modernization process in building that includes the development of modern production techniques and technology systems. Mechanized production activities are primarily focused on mass manufacturing and factory production, where work is centrally controlled (Lessing, 2006).

Industrialization has demonstrated a strong ability to lower costs, improve quality, and make complex products accessible to the vast majority of people.

A combination of several technologies can be incorporated into the construction process to circumvent the current issues that define the construction industry and to transform design, manufacturing, and construction processes. Construction industrialization is becoming the norm, with extensive use of advanced technology in activities ranging from off-site prefabrication to the transformation of construction into a mechanized and continuous process of assembly and installation of these prefabricated assemblies and parts. This approach's primary goals are to increase labor productivity, increase the rate of construction, lower costs, and make customization more affordable and improve overall quality and sustainability. According to a study done by Autodesk (2019), the five trends are summarized as follows:

i. Prefabrication

Prefabrication is the off-site fabrication of building elements and assemblies in a factory before transporting them to a site for assembly and installation. Prefabrication in construction dates back to the mid-1800s, but it has yet to gain widespread acceptance in the industry (Grills, 2013). There are two types of prefabrication systems: modular and panelized construction (Deltechomes, 2017). In panelized construction, also known as panelization, the structural components of the building are built in a factory and transported to the job site for assembly.

Prefabrication benefits address many of the issues associated with traditional construction methods, such as skilled intensive labor, variable quality, product and process inefficiencies, and high environmental impacts. Because building systems are constructed in a factory, automated machinery can be used, which prevents project delays due to a lack of skilled labor. In addition, using innovative equipment leads to higher product quality, greater efficiency, and, ultimately, lower costs. Construction waste is reduced through environmentally sustainable processes when it is carried out in such a controlled environment (Grills, 2013).

ii. Additive Manufacturing

Additive Manufacturing (AM), also known as 3D printing, is a way of producing objects by layering small deposits of materials. As an emerging building technology, the construction industry has begun to investigate AM. AM allows you to go from a 3D model of an object to a finished product with one touch and one machine, using a variety of materials such as steel, glass, ceramic, polymer, concrete, and more.

iii. Robotics

Robotics is the science of designing, building, and employing robots to perform tasks by combining the knowledge, experience, and creativity of mechanical, electrical, computer, industrial, and manufacturing engineering.

iv. Big Data and Predictive Analytics

Today's construction industry generates massive amounts of highly structured data via BIM and other project technology tools. The ability to process large amounts of data and extract useful insights from the data pool characterizes big data and predictive analysis (Bilal, 2016).

v. Internet of Things

The Internet of Things (IoT) is a network of physical objects that use electronic devices such as sensors and actuators to communicate and update information in order for the overall systems to perform optimally. The network can then establish a real-time feedback loop for better decision making (Saha, 2017). In the construction industry, this system is known as telematics, and it can be integrated into building systems to monitor operation conditions, performance levels, or physical states.

2.6. Industrialized Building System

The IBS is not a new concept in the construction industry; in essence, the growing demand for affordable housing, rising construction costs, and a lower productivity rate have led to the construction industry turning to the immense benefits of an industrialized building system. Despite its advantages, the implementation of industrialized construction systems has been gradual, owing in part to a lack of understanding and coordination among the parties involved (Oglesby, 1989).

The terms IBS off-site manufacturing and modular construction are frequently used interchangeably, and their clear-cut definitions are heavily dependent on user experience and understanding, which varies from country to country. The term was coined to denote a departure from the traditional paradigm of prefabricated systems. Though many prefabrication and industrialization terms are still in use, Industrialized Building System (IBS) has emerged as a term to represent those concepts.

The six standards characteristics IBS are transportation, production and assembly technique, mass-production, onsite fabrication, standardization, well-thought-out planning, and process integration (Badir YF, 2002). While almost all literatures emphasized the importance of offsite technology or factory production in IBS, they also emphasized the use of onsite technologies in IBS(Shaari, 2003). Building components which are often used in the IBS projects include walls, floors, beams and staircases (Abdul, 2005).

The IBS construction method can reduce resource waste while also providing high-quality results for customers (Thanoon, 2003). This type of construction method is an industrial process in which building components are designed, transported to the construction site, and then erected in accordance with plans.

Off-site construction methodology is defined by (Goodier, 2004) as "...the process of manufacturing and pre-assembly of specific amounts of building components, modules, and elements prior to shipment and installation on construction sites" (Goodier, 2004). Later, Quale and Smith expanded the definition as "...planning, design, manufacturing, and assembly of building elements at a place other than where they will be put to assist the speedy and efficient construction of a permanent structure" (Quale, 2016).

2.6.1. Classification of Industrialized Building System

Construction technology is being used to categorize various building systems. In this way, four broad types can be distinguished: systems using (1) timber, (2) steel, (3) cast in situ concrete, and (4) prefabricated concrete as structural and space enclosing elements. The geometrical configuration of the primary framing components of these systems can be further characterized as follows: (1) linear or skeleton (beams and columns) systems, (2) planar or panel systems, and (3) three-dimensional or box systems are the three types of systems available. (Warszawski, 1999).

The aspect of weight has a considerable impact on the component's transportability, as well as on the component's production process and installation method on site. The weight categorization provides the further benefit of distinguishing between the numerous fundamental materials used in component production, which could establish the system's characteristic on its own.

2.6.2. Characteristics of IBS

It's essential to go through the necessary characteristics for a successful industrialized construction system deployment. Each one is briefly addressed further below.

i. Closed System:

Production based on clients and production based on customers is the two kinds of closed systems. In this scenario, the client's preferences are crucial, and the manufacturer is always obligated to supply a certain component for a project. The first is production based on manufacturer design, which is created to satisfy a spatial demand, such as a unique requirement for various functions in the structure or a specific architectural design. Manufacturing based on the design of the manufacturer is the second category. Production based on producer (Manufacturers) design, on the other hand, comprises designing and building a standardized kind of building or a collection of building variants that can be produced using a common component type.

Only when the project's nature includes the following characteristics can the closed system be economically justifiable. (Warszawski, 1999).

a. Project Scale: If the project is large enough to spread design and manufacturing costs over the additional expense per component incurred owing to the unique design.

b. Architectural Approach: If the architectural design uses a lot of repetition and standardization. In this regard, an innovative prefabrication method that automates the design and production process can overcome the demand for many standardized components.

c. Demand: If there is enough demand for a typical style of building, such as a mass house, to allow for mass production.

d. Stakeholder Awareness: if a comprehensive marketing plan is in place to inform clients and designers about the possible benefits of the IBS project.

ii. Open System

In comparison to the closed system, this system allows for more design flexibility and maximum coordination between the designer and the producers. This technique is appropriate because it allows producers to make a restricted number of pieces with a limited product range while keeping architectural aesthetic value.

When two pieces from various systems are fixed together, such as when a joint or connection difficulty occurs, the open system provides a solution. In order to achieve the requisite structural performance, identical connecting technologies must be used.

iii. Modular Coordination

It is a coordinated and integrated system in which all components, would fit together without modification, even if the components and fittings are supplied by different suppliers (Trikha D. , 1999).

The objectives of are:

a. Building components can be minimized in terms of building components. It gives the designer the greater design freedom and choice by authorizing that each component be interchangeable with other similar components. This can also be achieved by using a relatively large basic measurement unit (basic module) and limiting the dimensions of building components to a recommended preferred size (Warszawski, 1999).

b. For easy adaptation of prefabricated components to any configuration and exchange them inside the structure. This is accomplished by referencing a common modular grid rather than other components when determining the location of each component in the construction (Warszawski, 1999).

This enables the architect to make building components in this size or a multiple of it. Although this notion appears to be simple to implement, it necessitates a significant deal of coordination and modification in the manufacturing process and component interface.

iv. Standardization and Tolerances

The primary requirement of modular coordination is component standardization for production, and such standardization of space and elements requires recommending tolerances at various construction stages such as manufactured tolerances, setting out tolerances, and erection tolerances, so that the combined tolerance obtained on statistical considerations is within the permitted limits (Trikha D. , 1999). The goal of both standardization and tolerance setting is to help create an efficient usage of production resources, as well as to best streamline the production process to the specific characteristics of the project.

v. Mass Production

One of the characteristics that enable the economic feasibility of IBS is manufacturing volume. It is economical only when mass production in volume is achieved, when capital expenditure in equipment and facilities can be distributed across a large number of product units without significantly inflated their eventual cost, so making the system affordable and accessible.

vi. Labor Specialization

Standardization of product units and mass production of components result in a greater degree of labor specialization where the process can be broken down into a large number of tiny, homogeneous tasks in the manufacturing process, leads to better workers production level (Warszawski, 1999).

vii. Production Facility

The initial substantial economic investment required to create a long-term manufacturing plant can only be justified if there is sufficient demand for the products. A temporary casting yard or factory on the project site should be explored as an alternative to reducing shipping costs to offset an additional operation cost. (Peng, 1986).

viii. Good Organization

Production and distribution of high products volume, specialization of labor, and centralization of production require efficient and competent management.

ix. Stakeholders Integration

A high level of coordination and integration must exist through an integrated system in which all of these tasks are executed under unified authority by various relevant parties such as the designer, manufacturer, owner, and contractor. (Warszawski, 1999).

x. Transportation and Equipment at Site

Even though casting a large-panel system can cut labor costs by up to 30%, these savings are offset in part by transportation expenses. Furthermore, when using a prefabrication system, the logistical constraints of transporting huge panels must be considered (Peng, 1986). Using a prefabricated construction method, the process of placing and assembling product units into their positions, particularly for multi-story buildings, as well as the availability of large cranes on site, must be considered (Warszawski, 1999).

2.6.3. Benefits and Limitation of IBS

I. Benefits of IBS

The construction industry can reap several benefits from IBS implementation, including lower labor costs, improved safety, less delays, higher product quality, increased productivity, and increased flexibility, none of which traditional building methods would normally achieve.

The IBS construction method emphasizes the ability to manufacture under industrialized manufacturing techniques in a controlled environment, transport, and then install on-site with little additional employees involved, offering a quick alternative construction method and has been taken into high consideration by construction industries worldwide (Taherkhani, 2019). Productivity and quality have also become primary incentives for contractors to choose IBS over conventional methods of construction (Azman, 2012). Furthermore, the benefits of using IBS in the construction industry as being ecologically friendly, since the components are manufactured off-site and according to a specific design, the utilization of resources will be optimized with waste generation being greatly reduced. The potentials of IBS are ranked from most useful to least advantageous (Azman M. N., ibid). Are as shown:

i. **Minimal wastage:** One of the most visible benefits of IBS is the optimization of processes and efficiency, which enhanced profitability by reducing material waste and, as a result, lowered building costs. Error and delay prevention through automation, on the other hand, will enable for fast intervention in construction issues.
ii. **Lower total construction costs:** Because the process employs cutting-edge mechanization and automation, it eliminates the need for experienced personnel. Since it requires far less effort. It makes the construction process more efficient.
iii. **Faster construction Time:** An industrialized building system allows for quicker construction time since precast elements may be cast at the factory and foundation work can be done on-site at the same time (Peng, 1986). IBS uses automated workflows to prevent delays on a construction project and to shorten the duration of each activity involved, thereby ensuring project completion on time. Because most of the work is done in a factory, there will be fewer delays due to weather, less need for coordination among subcontractors, and the activities can be completed around the clock.
iv. **Controlled Quality:** Working in a controlled, as is the case with IBS, produces in more precise and uniform product quality, as automation makes the work easier to perform. An element of an industrialized building offers greater quality components through the application of modern technologies, and strict quality assurance (Din, 1984).
v. **Design Flexibility:** An IBS offers for architectural design adaptability, reducing the monotony of repeating facades (Warszawski, 1999). An industrialized building system allows for flexibility in precast element design as well as construction, allowing separate systems to generate their own distinct prefabrication construction methods (zaini, 2000).
vi. **Reduction of site labour:** Prefabrication takes place in a centralized plant, reducing the need for on-site labor. This is particularly the case when there is a significant degree of mechanization involved. (Warszawski, 1999).
vii. **Neater and safer construction sites**: Employees working in a controlled atmosphere will lessen workplace hazards such as exposure to harsh weather factors, threatening access to electricity, and dangerous elevations.

Construction operations are carried out with fewer workers at risk owing using IBS.

II. Limitations of IBS

Industrial building system is still an emerging construction system. Despite its immense potential to bring solutions to the industry's pressing challenges, the method is constrained by several factors. Some of the major barriers to the adoption of IBS include social acceptance, high overall construction costs, a lack of qualified labor workforce, limited industry-academia collaboration, and a lack of compliance and regulatory authorities (Wong, 2015).

Some of the Limitations are:

i. **Social Acceptance:** The construction industry has a history of being hesitant to embrace technological breakthroughs, owing to the fact that most contractors are reluctant to switching from decades-old construction processes to something completely new to them. This is due to the misinterpretation of advances in technology such as robotics and automation, which has led to negative conceptions about robots replacing human labor and taking over jobs. Low-quality buildings, unappealing architectural homogeneity, and inflexible inventiveness and innovation are among the other misconceptions.

ii. **Expensive overall costs of construction:** Another barrier to IBS adoption is the substantial initial capital investment needed by construction companies to purchase these technologies and train human resources in the skills required to execute them. Construction enterprises must strengthen overall investment.

iii. **Lack of skilled labour:** Since IBS construction demands a high level of accuracy, all persons involved must have a comprehensive understanding of the procedures as well as the technical expertise to operate the appropriate software, hardware, equipment, and machinery.

iv. **Minimal industry-academia collaboration:** Minimal cooperation between industry and academic institutions in order to promote technological developments in the industry. Furthermore, there are no research institutions to facilitate collaboration between industry and universities.

v. **Lack of compliance and regulatory bodies:** Some prevailing regulations and policies do not contribute for the advancement of technology and the emerging needs of the industry, and there are insufficient building code procedures in the industry to ensure that standards are met efficiently when implementing advanced construction technologies such as IBS technologies.

2.7. Industrialized Building System for Mass Housing

The concept "mass-housing" refers to a uniform method to home production that has been used to accommodate the rapidly increasing housing demand in most developing economies (Ahadzie, Proverbs, & Olomolaiye, 2008). The concept of mass production inspired the mass housing (Karji, Woldesenbet, Khanzadi, & Tafazzoli, 2019). It referred to standardized house-units, built within the same project scheme, without consideration for any particular consumer, and often in the same neighborhood (Kwofie, Fugar, Adinyira, & Ahadzie, 2014).

Mass Housing projects have unique characteristics that make management substantially more difficult than 'one-off' conventional projects, needing a particular, one-of-a-kind management style and competence in their implementation (Turner, 2003) (Thorpe, 1999); (Ahadzie, Proverbs, & Olomolaiye, 2008); (Turner, 2003).

According to the above description of mass housing projects, the first feature is its physical attributes, such as the project's scale, the second is the nature of the designs, which is a repeating scheme, and the third is logistical complexity, which is carried out in multiple locations. In this regard, all attempted definitions of mass housing draw on the physical attributes of mass housing projects' inherent impact on performance, including Cost, Time, and Quality, in an attempt to achieve success in developing countries, forcing the construction industry to seek out more rational construction methods.

The solution lies in industrialized production. Traditional construction processes have limited the types of buildings, materials, and technologies that can be used. Industrialized construction, on the other hand, can offer greater versatility in terms of creating varieties, materials, and techniques. Individual freedom of choice will be expanded as a result.

Housing demand in Ethiopia is increasing rapidly, particularly in urban areas such as Addis Ababa. Using an innovative building technologies like IBS in construction can contribute to speed up the development of these low-cost housing units.

IBS construction is based on best practices that promote long-term affordability, quality, and efficiency, whereas traditional building techniques are centered on short-term economic considerations. These various advantages of IBS explain why there has been a recent surge in interest in IBS implementation.

The long-term sustainability and occupant comfort and safety of an IBS, which also considers a building's environmental impact throughout its entire life cycle while maximizing economic viability, Hervas, (2007) argue, the construction industry is regarded as a conventional industry that is unable to embrace or even resist change. Most of the negative perceptions about the usage of IBS shared by construction industry stakeholders are the result of a lack of information and knowledge about IBS developments (Hervas, 2007).

2.8. Critical Success Factors for IBS Implementation

2.8.1. The Critical Success Factors (CSFs) Definition

Even if CSFs originally appeared in the literature in the 1980s in response to the question of why some organizations appeared to be more successful than others, the concept of Critical Success Factors (CSFs) dates back to the 1960s (Carali, 2004). The definitions have a similar concept in that they outline the most significant parts that must be addressed in order to achieve concrete objectives.

(Méndez, (2008), define CSFs as carrying out specific actions in the correct manner in order to meet planned objectives (Méndez, 2008). Austin,(2002) on the other hand, defines CSFs as critical areas that must execute in order for the business to fulfill its objectives (Austin, 2002). Bullen, (1981) developed and popularized the CSF approach to defining and measuring an organization's performance.

While several definitions of the term CSFs have been proposed, the definition prop osed by Bullen and Rockhart, (1981) will be used in the context of this paper, which is "the limited number of achieve sustained competitive advantage will ensure succ essful competitive performance for the individual, department, or organization." (Bul len, 1981). The definition also added that, CSFs in the key areas where things must go right for the successful implementation of IBS, where the CSFs will be identified.

2.8.2. The Critical Success Factors for IBS Implementation

IBS is one alternative construction strategy that has the potential to shift the existing traditional construction industry's tendency toward a more systematic approach to the manufacture of construction materials and the construction process. To ensure the success of IBS implementation in the construction industry and the transformation from conventional to IBS, tremendous attention should be paid to several critical areas that are critical to attaining a transformation, and action must be taken to identify the factors that may influence IBS implementation in order to benefit and profit from the system.

All relevant critical success criteria suggested by previous researchers were examined and compiled throughout this study. From the 73 articles and literature evaluated at the literature review phase by the researcher, 31 influencing factors were identified. The list of factors was compiled from a variety of sources of information. Eight critical success factors are identified, then further subdivided into 31 sub-factors. Table 1 summarizes the factors and sub-factors that have been compiled based on literature reviewed.

Table 1: Categories of factors compiled from literatures review by the researcher & Sources

NO.	INDICATORS CATEGORY	AUTHORS (Source)
1	KNOWLEDGE FACTORS	(Palmer, 2003)
		(Nawi M. N., 2015)
		(Gibb A. , 2001)
		(Goodier, 2004)
		(Warszawski, 1999)
2	MANAGEMENT FACTORS	(Bari, 2012)
		(Pan W. G., 2007)
		(Kamar K. A., 2010)
		(Kamar K. A., 2009)
		(Lu, 2008)
		(Lu, 2008)
		(Blismas, 2007)
		(Cheung, 2012)
		(Hassim, 2009)
		(Harjeev, 2011)
3	PRODUCTION AND LOGISTICS	(Luo, 2015)
		(Gibb A. G., 1999)
		(Gibb A. , 2001)
		(Cheung, 2012)
		(Kamar K. A., 2010)
		(Hashim, 2011)
		(Onyeizu, 2011)
		(Haas, 2001)
4	INTEGRATION FACTOR	(Nawi M. L., 2011)
		(Arashpour, 2018)
		(Yunus, 2012)
5	COST FACTOR	(Bari, 2012)
		(Shamsuddin, 2015)
		(Samaras, 2013)
6	SUPPLY CHAIN AND MARKET FACTOR	(Marinez-Moyano, 2006)
		(Luo, 2015)
		(Nagurney, 2006)
		(Berawi M.A., 2012)
		(Fauzi, 2018)
		(Malik, 2006)
		(Rashid, 2006)
		(Morledge, 2006)
		(Parid, 2003)
		Pan, W., et al., (2008)
		(Hussein, 2007)
		(Dzulkalnine, 2017)
7	TECHNOLOGY FACTOR	(Dina, 2008)
		(Holland, 2000)
		(Mohamad M. , 1999)
		(Kamar K. A., 2010)
		(Ikechukwu O., 2011)
		(Pozin, 2017)
8	GOVERNMENT POLICIES and REGULATION	**(Nawi M. L., 2011)**

A. Knowledge and Expertise Factors

Apparently, a high level of specialization stems from a high level of training and professional education. A lack of knowledge and skill in the field of IBS construction would result in financial aspects that concern the cost of construction. Architects, contractors/producers, developers, and practitioners had a substantial impact on the success of innovative modern prefabricated housing schemes because of their contributions to the development process and their participation in decision-making (Palmer, 2003).

i. **Training & Education:** To realize the advantages of utilizing IBS to its maximum is through educating architects and engineers in a systematic way, taking the above mention points and arguments, an investment in training to master IBS skills is inevitable and critical to succeed in IBS (Nawi M. N., 2015). To realize the benefits of utilizing IBS to its full potential, architects and engineers must be educated in a systematic manner. Taking the preceding reasons and arguments into consideration, an investment in training to learn IBS skills is inevitable and critical to success in IBS.

ii. **Labour skill:** A majority of construction workers in developing countries are ordinary labourers with limited skill sets. Skilled labor, backed up by appropriate training at every level, is critical to the success of IBS implementation. As a result, a broader and more complete training program must be implemented to meet the need for these specialized talents (Gibb A. , 2001) (Goodier, 2004) (Palmer, 2003).

iii. **Skill of Expertise:** Compared to traditional methods, IBS requires a high level of competence and precision As a result, systematic education and formal training can provide expertise and personnel with a comprehensive knowledge about issues relating to the planning, design, and installation of building components (Pan W. G., 2008).

B. Management Factors

Effective management contributes favourably to construction performance since it can be efficiently applied and monitored during each step of the project. In an industrialized building system, management factors are the niche of the entire supply chain system (Bari, 2012). Ismail,(2012) claims that it depicts a control process and how something is done or used. The following management factors are considered the critical influencing factors in the deployment of IBS. Good working collaboration, an effective communication channel, team members involved in the design stage, extensive planning and scheduling, risk management, on-site management, technical aspects, and top-down commitment are among the factors chosen.

i. **Good working collaboration:** A good working partnership will solve the difficulty of complex system interaction and ensure an efficient process sequence in the manufacturing plant and on the job site. (Lu, 2008). Collaboration between all parties is critical in the initial works of the IBS process to ensure the success of IBS project implementation. This collaboration will address the issue of difficult interfacing between systems and enable an efficient process sequence in the production plant and on-site (Kamar K. A., 2010).

ii. **Effective Communication Channel:** Communication channels refer to how information moves within an organization, particularly in construction projects where information goes forwards, backwards, and sideways. An effective communication channel across the supply chain must be built in order to coordinate the process and deal with crucial scheduling issues from the start to the end of the project (Pan W. G., 2007), (Kamar K. A., 2010). Due to a lack of communication in the IBS project, additional costs and time will be incurred due to rework and on working drawings (Kamar K. A., 2009).

iii. **Team Members Involvement during the Design Stage**: The design phase is a critical and first step in IBS. Given that the philosophy, concepts, and preferences of the stakeholders involved influence the outcome of any design, it is critical to integrate team members during the design stages when using IBS in design process. Working without a design team limits the benefits that can be obtained through the use of this method or the ability to overcome the issue at a later stage (Blismas, 2007).

iv. **Extensive Planning and Scheduling**: To guarantee the success of an IBS project, efficient planning and scheduling can ensure that all stakeholders comprehend their respective duties. All stages of the project are incorporated to ensure successful IBS project execution, including early works, component fabrication at the plant, transportation to the building site, installation, and completion (Cheung, 2012). Extensive task planning and scheduling in advance is required to improve project performance, collaboration, scope control, and assure a smooth and productive sequence (Kamar K. A., 2010).

v. **Risk management:** Risk management is essential at all phases of the IBS process. To address possible project risks such as late design revisions, late payment, and contract disputes, a risk management strategy is required (Hassim, 2009).

vi. **Top-down commitment:** The commitment of the project manager is also needed for the successful execution of an IBS project. Top-down commitment is required throughout the IBS process, including early works, component fabrication at the plant, transportation to the construction site, installation, and completion (Harjeev, 2011).

vii. ***On-Site Management:*** Standardized processes and assembly lines limit the capacity to adapt and respond to changes, needing rigorous on-site monitoring. Without a comprehensive and thorough on-site management strategy, all project stakeholders, including clients, contractors, suppliers, and consultants, operate without clear procedures (Luo, 2015). This raises the possibility of poor quality, safety-related incidents, time overruns, cost overruns, and other risks.

viii. **Technical Factor:** These factors lead to construction delays and poor quality. "Errors and defects attributed to poor design abilities of designers," "limited technique in assembling and lifting precast components on site and incompetence of technology and equipment" are all technical factors involved with adopting (Luo, 2015).

C. Supply Chain and Market Factors

Supply chain management is the management of a system of interconnected companies involved in the final provision of product and service required by end customers. In terms of competitiveness and efficiency, the fragmented construction sector has a significant influence on the IBS supply chain. IBS requires a high level of supply chain coordination and integration across the design, manufacturing, and construction stages. Due to the fragmented structure of the prefabrication industry and difficulties in locating and establishing effective collaboration among skilled contractors, suppliers, and consultants in the local market who can implement IBS would escalate production cost, exacerbating the housing affordability challenge (Luo, 2015).

i. ***Management of supply chain and logistic:*** As a function, a supply chain system is built up of organizations, people, technology, activities, information, and resources that are all engaged in bringing a product or service from a supplier to a customer (Nagurney, 2006). The supply chain and logistics are crucial at all stages of the IBS process, including initial works, component manufacture at the plant, transportation to the building site, installation, and completion. Ensuring that supplies are provided at the appropriate time and location can help ensure the effective execution of an IBS project. However, challenges pertaining to manufacturers' expectations for just-in-time delivery, which decreases warehousing and storage expenses, reduces lead time, improves productivity, improves quality, and forecasts material demand before purchasing from suppliers, are some of the issues impeding its performance (Berawi M.A., 2012).

ii. ***Procurement Management:*** It is a significant aspect that contributes to the project's success (Morledge, 2006). Defined as a means of organizing and managing the project's multiple stakeholders, with an emphasis on creating contractual relationships between them (Rashid, 2006). Based on Traditional procurement system, the design and construction work will be made in sequential and they are conducted by different parties. The convenience of manufacturing and installing components is a factor in the design of an IBS construction project. though in practice using the traditional procurement approach, the design and construction work would be done sequentially independent parties where contractors and manufacturers of IBS components are only involved after the tender stage of development value chain. If IBS is implemented, there will be a necessity for integration among key stakeholders throughout the design stage in order to minimize additional redesign costs (Hussein, 2007). Acknowledging the above fact, procurement strategy and contracting must also be improved in order to achieve long-term success implementation of IBS (Pan W. G., 2008).

iii. **Business and Marketing strategy:** The current shift in marketing strategy is being driven by a global trend shift in the construction industry. Firms are increasingly competing with or working with emerging innovation-driven organizations. Developing a business integration platform via technology and knowledge transfer, as well as a clear business and marketing plan to persuade local developers to participate in this system; can assure the successful implementation of IBS in Ethiopia.

iv. ***Payment Issues:*** The stream of funds in a construction project is a critical component in achieving the project's goal. Payment complications, as compared to the traditional technique, can have a major impact on the project's productivity and development progress (Dzulkalnine, 2017). The stream of funds in a construction project is a critical component in achieving the project's goal. Payment complications, as compared to the traditional technique, can have a major impact on the project's productivity and development progress. (Dzulkalnine, 2017).

D. Integration Factors

The construction industry's distinct character, which is centered on one-time projects and temporary partnerships, has a significant influence on the flow of communication and coordination among team members, contributing to a contentious relationship. Some of the strategies available in the current construction industry to improve integration of the design and construction process are integrated procurement such as, Design and Build, Construction Management, concurrent engineering, lean construction, supply chain management, constructability (or build-ability), and partnering.

i. **Integration of Resources:** Prefabrication networks may be expanded through process integration and cross-training multi-skilled resources, as production networks will be able to flexibly address fluctuations in demand and resource availability (Arashpour, 2018).

ii. **Team Integration:** As a result of existing construction practices related with fragmentation constraints, such as professional segregation and lack of coordination among all project team members hinders the success of IBS (Nawi M. L., 2011).

iii. **Integrated Processes Assessment:** IBS implementation is not achievable without well-defined, decision-making tools. According to Yunus, (2012), Cooperation among key stakeholders is another major issue in the IBS strategy. Traditional construction approaches exclude contractors and manufacturers from participating in the design phase of a project, which typically results in design modifications and increased costs, as well as a reduction in quality (Yunus, 2012).

E. Technology Factors

Technology plays an important role within a project team as a medium or effective instrument for organizing work, fostering participation, and communicating information. The usage of appropriate technology is crucial when it comes to developing an organization's structure in order to garner successful integrated teams (Koskela, 2003). In-person communication and meaningful teaming may not always be possible due to physical, temporal, or departmental constraints; in this case, technology can play a role as a means of communication among team members to help them integrate their activities and keep the entire team up to date with project-related documents, progress, and challenges (Holland, 2000). In order to manage detailed design and construction processes, costs, and schedules in a project, technology can assist communication and teamwork (Mohamad M. , 1999).

i. **Utilization of Software:** There are many technology applications or tools used in the construction marketplace currently, such as groupware system (i.e., Building Information Modeling (BIM), Computer Aided Design (CAD), Computer Aided Manufacturing (CAM), material database, and decision support software, which would significantly aid communication and coordination between parties towards successfully integrated project team (Kamar K. A., 2010). BIM, in particular, has the ability to boost IBS construction by recognizing redundancy, contributing to greater cost reductions through mass production.

ii. **Information Communication Technology:** Because communication is such a crucial component of construction projects, the construction industry is confronted with the need for and application of information and communication technology. As information and communication technology (ICT) evolves, there are potential to increase communication among construction project participants and enable more effective and efficient communication (Ikechukwu O., 2011). The construction industry is constantly challenged to adapt and enhance existing business practices in order to become more customer-oriented, competitive, and productive by incorporating ICT as an integral component of the construction process. One of the five challenges that impede maximum performance of the IBS project is a lack of ICT (Pozin, 2019).

F. Cost Factors

Cost is certainly a critical determinant in any business venture, especially in the construction industry. The following are some of the cost factors that impact IBS system adoption:

- **i. Initial investment cost:** This comprises the costs of creating a manufacturing facility, as well as the price of installing machinery, equipment, and technology (Samaras, 2013). Regular funding is one way for accomplishing a well-organized IBS implementation that need a revenue stream since the cost is excessively high for investors and contractors.
- **ii. Operational costs**: A cost associated in the normal day-to-day operation (Samaras, 2013), which includes Cost of labour, Management, Training, Transportation and costs of utilities. Despite the fact that the IBS reduced dependency on manual labor, its reliance on highly skilled employees, that are in limited supply in developing countries and hence require a higher wage, makes operation costs critical
- **iii. Cost Estimation Models:** Cost estimate methods in IBS building projects are important for IBS to be so adaptable in response to multiple advancements in the construction industry. As a result, developing an integrated costing system that can give a rational method for accurately determining a realistic project cost is critical (Shamsuddin, 2015).

G. Government Policies and Regulation

The most crucial aspect in enabling construction companies to operate together in an integrated and collaborative manner is government policies (Nawi M. N., 2015). Government policies must always be harmonized with the industry's shared vision in order for effective decision-making to materialize.

i. Government Policies:

Considering companies and industries typically update their policies to line with government policy, favourable national policy is a significant component that greatly influences the promotion of new techniques or products, particularly in the construction industry. Furthermore, for successful IBS implementation, governments have to provide supportive policy mechanisms for the construction manufacturing industry, such as boosting private enterprise capability and capacity, strengthening research and development and commercialization, reducing construction levy for contractors, a leasing model for purchasing machines, financial assistance and tax exemption, and reductions in import duty and sales tax on heavy machinery. The inadequacy of government incentives and marketing to entice housing developers to embrace such innovative construction techniques, as well as inadequate enforcement of government incentives offered to developers by local authorities, can compromise IBS's successful implementation.

ii. Regulations:

Understanding the environmental standards and requirements of the local authorities would allow the project team to perform the project with little rework.

iii. Standards (Modular Coordination):

It is a unified and coordinated approach to dimensioning spaces, components, and fittings so that they all fit together without cutting or extending, even if the components and fittings are produced by different manufacturers (Trikha D. , 1999). The purpose of defining standards is to provide a framework on which the variety of kinds and sizes of building components may be minimized, with each component designed to be interchangeable with other equivalent ones, giving the architect more flexibility and choice. By using a rationalized construction process and limiting the proportions of building components to established optimum sizes. Standardization also allows for an easy incorporation of prefabricated components into any design and interchange-ability within the building (Warszawski, 1999).

H. *Production and Logistics*

i. **Facilities (Level of Automation):** Prefabrication takes place in a centralized plant, decreasing the need for on-site labor. This is certainly relevant when there is a significant degree of mechanization and automation (Warszawski, 1999). Since this kind of development requires a greater level of mechanization, the level of production and assembly automation influences the duration of development, cost of construction, and the quality of the project outcomes.

ii. **Transportation:** Transportation concerns, such as size and weight of precast components constraints, route restrictions, permission, and the availability of lifting equipment, are among the challenges in handling IBS construction, according to (Haas, 2001). Additional lift planning is required after the components arrive at the building site. The complexity of the lift usually increases as the level of IBS utilization. Construction schedules, site design, crane expenses, will all be affected by transportation constraints, according to research conducted by (Warszawski, 1999). The length of prefabricated components should not exceed 12 meters, which is the standard truck length, according to (Azman M.N.A., 2012). The height of prefabricated components on the trailer should not exceed a highway height restriction of 4.8 to 5.1 meters, while the weight of precast concrete components should not exceed 6,350 kg to guarantee the crane can easily move and install it on site.

iii. **Modularization (Standardization):** One of the success factors in the utilization of IBS is component standardization. Due to the lack of component standards, the same components cannot be used for multiple projects

(Hashim, 2011). Architects, Engineers, and contractors consider building component standardization to be the most important factor driving design innovation. Limited standardization raises expenses due to design costs and mold that cannot be utilized for another project (Hashim, 2011).

iv. **Factory Location:** The location of the production plant is one of the criteria that influence the performance of IBS implementation. It has a significant influence on the cost of construction. Transportation constraints induced by the factory's location with respect to the building site is one of the challenges in managing IBS construction. The distance between the production facility and the development location should be between 50 and 100 kilometers (Azman M.N.A., 2012).

v. **Production Capacity:** Given the huge demand for components for major housing projects, production capacity is a key impediment to the efficient use of IBS for mass housing development. Consistent delivery of precast concrete components in accordance with the appropriate delivery schedule, quantities, and arrival orders is dependent on mass production and production capacity and can implicitly encourage contractors to use the system, eventually making IBS the preferred construction System. Table 2 presents summery of 31 factors that influence IBS implementation success.

Table 2: List of Critical Success Factors catagorised from source shown in Table 1

CSF CATEGORY Level one	Alternative CRITICAL SUCCESS FACTORS(CSF)	CSF CATEGORY Level one	Alternative CRITICAL SUCCESS FACTORS(CSF)
KNOWLEDGE FACTOR	Training & Education	PRODUCTION AND LOGISTICS	Facilities (Level of Automation)
	Labour skill		Transportation
	Skill of Expertise		Modularization(Standardization)
			Factory Location
TECHNOLOGY FACTOR	Utilization Of Software		Production Capacity
	Information Communication Technology (ICT),		
INTEGRATION FACTOR	Integration Of Resources	COST FACTOR	Initial investment cost
	Team Integration		Operational costs
	Integrated Processes Assessment		Cost Estimation Models
GOVERNMENT POLICIES & REGULATION	Policy Framework	MANAGEMENT FACTORS	Good working collaboration
	Regulations		Effective Communication Channel
	Standard /Modular Coordination /		Team Members Involvement During the Design Stage
			Risk management
SUPPLY CHAIN AND MARKET FACTOR	Management of supply chain and logistic		Extensive Planning and Scheduling
	Procurement Management		Top-down commitment
	Business and Marketing strategy		On-Site Management
	Payment Issues		Technical Factor

2.9. IBS: The Malaysia Experience

Malaysia, being a developing country and one of Asia's fastest-growing economies, has the highest level of urbanization, with 76 percent of the total population residing in cities in 2019 (Bank, 2022).As a result of the increased concentration of urban inhabitants, Malaysians have increased the demand for affordable housing units. Malaysia's government shifted its focus to mass production and prefabrication construction technologies in order to meet the rapidly growing demand for housing. This strategy prompted Malaysia's construction industry to investigate construction industries in other nations that had already utilized prefabrication technology. In Malaysia, the gradual development of the IBS systems is accounted for related government initiatives to encourage the technology, particularly in the housing sector. In recognition to Malaysia achievement to provide affordable housing to urban residences, Malaysian's experience can also be used as lesson for developing countries such as Ethiopia undergoing rapid urbanization and demographic transition to adopt IBS for housing projects where supply of housing is a challenging issue.

Malaysia's construction industry coined the word "Industrialized Building System" (IBS) to describe the use of construction industrialization through the use of prefabricated building components. The construction industry has begun to embrace IBS as a strategy of enhancing building quality and productivity, eliminating occupational safety and health problems, alleviating challenges to obtain qualified staff and reducing dependency on manual foreign labor, and eventually cutting total construction costs (Pan W. G., 2008).

2.9.1. IBS Adoption in Malaysia (The Chronology)

Development of IBS in 1960s: In Malaysia, IBS has been employed since the early 1960s, when the Malaysian Public Works Department (PWD) and Ministry of Housing and Local Government (MHLG) traveled numerous European countries to assess housing development schemes. The government established the Ministry of Housing and Local Government (MHLG) the same year to focus on housing construction.

Development in 1964 to 1970s: Following a successful tour in European nations with advanced development in the technique to get an insight about IBS in 1964, the government launched its first IBS project, with the goal of reducing delivery schedules and constructing affordable and high-quality housing, start to employ use of a pre-cast concrete wall system with large panels and plank slabs.

Development in 1970s to early 1980s: In 1978, the Penang State Government IBS was the first to use IBS prefabrication technology in the construction of a low-cost high-rise residential building to meet the ever - growing need for housing in

1978. Nonetheless, the building industry's industrialization was never sustained throughout this time due to the failure of prior foreign fabricated systems implemented which were incompatible with Malaysia's climate and social customs caused the industry to resist transitioning to IBS as a construction approach. Simultaneously, innovation in the form of precast concrete sandwich wall panels developed in Europe has gained a lot of popularity in Malaysia, with hot climates due to better insulating properties and has been employed in various pilot projects in Malaysia throughout the 1970s and 1980s. (Trikha D. A., 2004).

Development in 1980s to 1990s: During the early 1980s, structural steel components were widely used, notably in high-rise constructions in Kuala Lumpur. Despite the fact that the technique was established in another country, local contractors have customized it to meet local needs. The usage of precast concrete technology in housing construction grew in the 1990s as the need for new settlements increased. Steel is replaced with high-quality film-coated plywood in a revolutionary mold technique. The design is simple to deconstruct, handle with a small crane, and can be simply modified to suit design specifications. Framing, modular, and partially pre-caste systems are some of the other systems employed (Sarja, 1998).

Development in 1990s to 1998s: Several national iconic structures were constructed using hybrid IBS technologies, which are a blend of IBS and conventional construction, during the booming period of Malaysian development from 1994 to 1997.

Development in 1998 – 2008: Most Malaysian private companies have collaborated with international experts to provide solutions for their IBS projects. As a result of technology transfer, many people have gained better understand in IBS technologies. The use of IBS as a development strategy is actively expanding in Malaysia, where Malaysians have created their own IBS technology. New government construction projects were aggressively promoted in 2004 to use at least 50% IBS content in their construction components. In terms of quality and architectural appeal, the current generation of IBS-enabled buildings outperforms the preceding generation. In 2005, the government committed to build 100,000 affordable housing units using IBS. As a tax incentive, the Acceleration Capital Allowance (ACA) was introduced in 2006, allowing IBS manufacturers to claim ACA for expenses incurred in the acquisition of steel molds for the fabrication of precast concrete components, which should be claimed within three years (Hamid, 2008).

Development in 2010s: One of the most significant achievements in IBS policy is the regulation of the use of IBS in the construction of public buildings. In November 2008, the Malaysian Treasury issued a Treasury Circular Letter to all Malaysian government agencies, now known as SPP 7/2008, directing them to increase the

IBS content of their planned construction projects to a level not less than 70 points of the IBS score, and IBS must be incorporated as part of the contract document for tendering (Hamid, 2008). The move was made in order to build enough traction for IBS component demand to extend across the country. To oversee implementation, the government established the National IBS Secretariat. It entails cross-ministerial cooperation to guarantee that the policy is implemented effectively. Between 2008 and 2010, roughly 331 projects were granted and IBS was implemented in their respective projects under 17 ministries.

2.9.2. Experiences and Lesson Learned

i. **Government Policy:** For public building projects, the industry is mandated to use the IBS system. As a result, the construction industry, both private and public, is compelled to participate in IBS implementation. IBS must be included in the procurement contract document, which generates enough demand for IBS components with significant national impact. As a result of this strategy, the cost of construction in IBS has been significantly reduced. Adoption was traditionally motivated by desire rather than feasibility. In Malaysia, the IBS system is currently competitive, and cheaper, when compared to traditional techniques, depending on the type of project, system, and volume.

ii. **Incentive:** The tax incentive introduced has significantly increases the engagement of both private investors and public project developers, resulting in enough momentum for IBS component demand to spread throughout the country.

iii. **Standardization and Hybrid System (Open Building System/OBS/**: Unlike the prefabricated closed system, which enables just a few industry companies to participate, the IBS in Malaysia advocates an open or hybrid approach and invites complete industry involvement. The IBS supply chain is made up of modular component-based goods that can be manufactured and exchanged between projects, allowing clients to mass modify. As a result, a firm that can tap into the IBS supply chain will be able to provide systems rather than individual parts. It is critical to standardize the construction sector in order to create an Open System. The OBS concept is analogous to how internationally standardized USB ports have developed in the ICT sector.

iv. **Modular Coordination:** Modular Coordination was a key technique that enabled manufacturers and installers to enter the market, lowering the cost of IBS components. The concept enables component uniformity in design and production. It is a dimension and space coordination concept in which structures and components are dimensioned and positioned in a fundamental unit or module known as 1m, which equals 100 mm.

v. **Partnership and Innovation:** Several private firms have collaborated with international partners and overseas experts to provide solutions for their IBS initiatives, actually results in technology transfer and in-house knowledge and skill development about manufacturing and design capabilities to create systems, allowing them to be less reliant on current producers abroad.

2.10. Precast Concrete System

Precast concrete refers to concrete products and one of IBS system, manufactured in a factory setting at a permanent location or in a temporary casting yard on a construction site and then assembled as a building system. Off-site manufacturing is prefabrication method that entails "producing all or part of a product manufactured at locations other than its final location" (Cooper, 2004). As an option for low-cost housing, it grabs the attention of housing developers due to its potential benefits discussed previously.

2.10.1. Benefits of Precast Concrete System for Mass Housing

Precast concrete systems provide a number of advantages, including the potential to reduce waste, enable construction waste recycling, reduced construction project costs, improve site safety, improve quality, process standardization, reduce lead time, and contribute to environmental sustainability (Y. Chen, 2010).

2.11. IBS Precast Concrete Construction in Ethiopia

In the late 1970s and early 1980s, housing demand was so overwhelming that the government, as the sole provider of housing, was unable to fulfill the ever-increasing need. As a result, it was decided to implement a new building technique, concrete structural element prefabrication. Under the previous Ethiopian Building Authority (EBCA), the Prefabricated Building Parts Production Enterprise (PBPPE), a pioneering prefabricated construction sector, was established in Ethiopia in 1985 with technical assistance from former Yugoslavia. The establishment of a prefabricated material plant in Addis Ababa introduced new approaches to the construction business, with the goal of meeting the city's vast construction demands. Furthermore, it was designed to accommodate the ever-increasing demand for housing in the shortest period of time possible while eliminating the critical need for timber for formwork.

The other prefab factory is YBEL industrial plc. Established in 2009 in Addis Ababa develop buildings by applying prefab technology. It is the first and pioneer private prefab factory and in adoption of mechanized agro-stone panels and magnesium board technology in Ethiopia in the prefab building industry.

In various parts of Ethiopia, the firm has built residential homes, project camp houses, guest houses, and other structures out of steel frames, agro-stone panels, magnesium board, and PVC windows and ceiling (Birhanu, 2020). In 2018 a private owned company called EDAB, start to apply the modular construction method to construct public housing in Addis Ababa as a demonstration project in collaboration with Addis Ababa housing corporation .

Prefabricated construction technique in Addis Ababa is started when Ministry of Urban development and Housing commission the construction of the first 500 apartments to Cooperativa Muratorie Cementisti (C.M.C) of Ravenna Italy in 1990. This was a unique housing project since it was the first in Ethiopia to efficiently use precast concrete elements, particularly by a foreign construction business introducing a variety of possibilities. The UN Economic Commission for Africa head office complex in 1994 and the Patriarch Palace Building project in 1996, both in Addis Ababa, were built with precast concrete produced by the C.M.C. This corporation is now only involved with one government-owned office building in ICT Park. Prefabrication technology is currently being used at a very low rate compared to previous years. The previous PBPPE is now integrated with other governmental owned construction companies and is called Ethiopian construction Works Corporation.

With the conception and implementation of IHDP, the use of industrialized prefabricated construction materials begins to revive, although with limited applicability. However, the efforts constrained with product diversification and quality issues. The IHDP construction system is based on the ideas of reconstruction in postwar Germany. It employs the low-cost housing (LCH) approach, which includes a concrete pillar and slab structure. The usage of construction machinery is kept to a minimum. Instead, customized MSEs are employed to create jobs via a labor-intensive approach. (UN-Habitat, 2010).

In comparison to other countries, Ethiopia's PMC is quite low; condominium housing accounts for only 6.7 percent of all prefabricated buildings. The Ethiopian government, on the other hand, intends to use PMC to construct roughly 75,000 condo houses during the GTP II. This indicates a huge gap in the implementation of PMC in the housing development program (Birhanu, 2020). SMEs produce prefabricated construction materials such as precast beams, hollow slab blocks, and hollow concrete blocks (UN-HABITAT, 2011).

According to Yidnekachew (2018), the priority rank of the IBS, shows that the top three systems are found to most suitable for Addis Ababa. The three systems are all precast concrete systems. They are precast concrete slab and stairs, precast concrete column, beam, cross walls, floors and stairs, and precast concrete wall panels. Load-bearing, easily to assemble, sound and fireproof, ideal for use in medium to high-rise residential buildings, and cost-effective in large-scale manufacture are some of the common qualities of IBS (Yidnekachew D., 2018). The techniques are around 25% more productive than traditional construction methods (Pan Y. , 2007). They are open systems capable of performing with both standard and industrialized components. The three systems are semi-industrialized because they only supply components of the building and leave out the finishing and mechanical-electrical aspects.

2.11.1. Utilization level of Precast Concrete System in Ethiopia

Even if the technology is introduced 3 decades ago the highest percent (87 %) of prefab buildings were constructed and concentrated in Addis Ababa (Birhanu, 2020). The distribution or expansion of the technology was restricted in a specific area. The second (4 %) were found in Beshoftu and the least (2 %) were found in Adama, Hawassa, Dewele and Galafi. This implies that the expansion of PMC in the other cities of the country was extremely limited. The distribution of prefabricated houses to regional cities decreases as distances from the factory (AA) increase due to transportation and logistics problems. This is one of the challenges hindering the adoption of this technology in the country (Birhanu, 2020). Half (53.3 %) of the past prefabricated buildings were constructed for the private sector. This denotes that there is a good awareness and acceptance on private sectors than the government on the effectiveness of prefab technology. The government sector follows by 46.7 % (Birhanu, 2020).

2.12. Summary of Major Findings

Despite the multiple benefits of IBS in terms of cost, quality, construction time waste reduction, and environmental sustainability, standardization adaptability entails a significant level of experience and training, as well as a large initial investment which are of the major impediments to the widespread use of modular building (Warszawski, 1999).

Good working partnerships, a competent workforce, an effective communication channel, financial competence, and a risk management strategy were among the critical success factors to consider for successful IBS implementation in a developing nation.

Marketing strategy and design standardization advancements, as well as the introduction of favorable project delivery mechanisms such as a public-private partnership, will promote IBS competent contractors. To boost housing supply, it is necessary to build a systematic and effective partnership among stakeholders, as well as to include IBS construction techniques into educational programs.

Even though IBS technology has been available in Ethiopia for decades, it is still underutilized.

The identification of critical criteria for success will allow stakeholders to plan and implement a more comprehensive IBS implementation strategy in order to reap the benefits of IBS for large-scale housing projects.

The influence of various factors varies depending on the circumstance. Based on a comprehensive literature review, the primary CSFs recognized as critical in the Addis Ababa housing development context have been classified into eight indicators, with 31 alternative variables included.

Precast concrete systems of three types (precast concrete slab and stairs, precast concrete column, beam, lateral walls, floors and precast concrete wall panels) are ranked top and found to be suitable IBS systems for medium and high-rise residential buildings (Yidnekachew D., 2018). These IBS systems are appropriate owing to their economic competitiveness, utilization of local material resources, lower energy consumption, ease of construction, and compatibility with traditional components. These are some of the primary reasons for implementing IBS in house development, as well as for addressing the housing supply crisis by boosting construction productivity (Yidnekachew D., 2018).

2.13. Literature Gap

A range of sources are used in the literature review process to get an overall understanding of IBS, including its advantages, characteristics, and classifications, particularly in the housing construction industry. The experience of several nations in adopting IBS within the context of their unique goals and context is also thoroughly investigated.

Several researches have been conducted in various countries, including Africa, Asia, and Europe, specifically to examine the success factor for the implementation of IBS and its potential use for mass housing projects, notably in Malaysia.

In the context of Ethiopia, researches in the application of precast concrete system as a structural element, barriers for the implementation of off-site method of construction and also the utilization level of perfected materials had been done by different scholars with a suggestion of further researches in this theme.

Rather, past research did not examine the factors that could possibly unlock the utilization of IBS for housing developments. Taking these research gaps into account, this research aims to identify the critical success factors for the successful implementation of IBS in Addis Ababa housing projects, as well as the potential benefits, including cost analysis, of these systems in comparison to the conventional building approach.

CHAPTER THREE

3. RESEARCH METHODOLOGY

3.1. Introduction

This chapter discusses the research design and methodology used in acquiring the necessary information to answer the research questions. It specifically presents the research questions, describes research approach and techniques and outlines sampling techniques in terms of sample size and selection, validity and reliability of the research, data collection methods and data analysis methods. The detail about the methodology and methods of the study are discussed in subsequent sections.

3.2. Research Approach

A mixed method approach is applied in the research process. The main reason for adopting mixed method research is that it provides a more complete understanding of the research subject than either qualitative or quantitative approaches independently. The three techniques used for combining quantitative and qualitative data in these mixed method research are, by combining, integrating and, connecting both data type from the both primary and secondary data type and all data collection step so that one source builds on or helps to explain the other, and embedding one secondary or supporting source of data into a larger source of data to provide additional information in a study.

3.3. Research Design

The general framework of the study is referred to as the research design. Figure 1 shows a summary of the major activities of the research. The research process is divided in to three phases, where consecutive steps are included in each phase. The first phase is an exploratory followed by primary data collection phase and data analysis and recommendation phase.

3.4. Methodology

The survey methodology is used in the research. Survey research is used for a multitude of reason, including the following: Surveys are flexible in terms of the types and range of variables that may be investigated, it need less time and money to organize and administer, and it is simple to generalize. In addition, survey research allows to acquire information from large samples of the population, and to establish particular elements of a group statistically while examining the relationships between variables. Since survey data is obtained from individuals, survey research employs a sector of the population from which the findings may be extrapolated to the entire population (Pinsonneault, 1993).

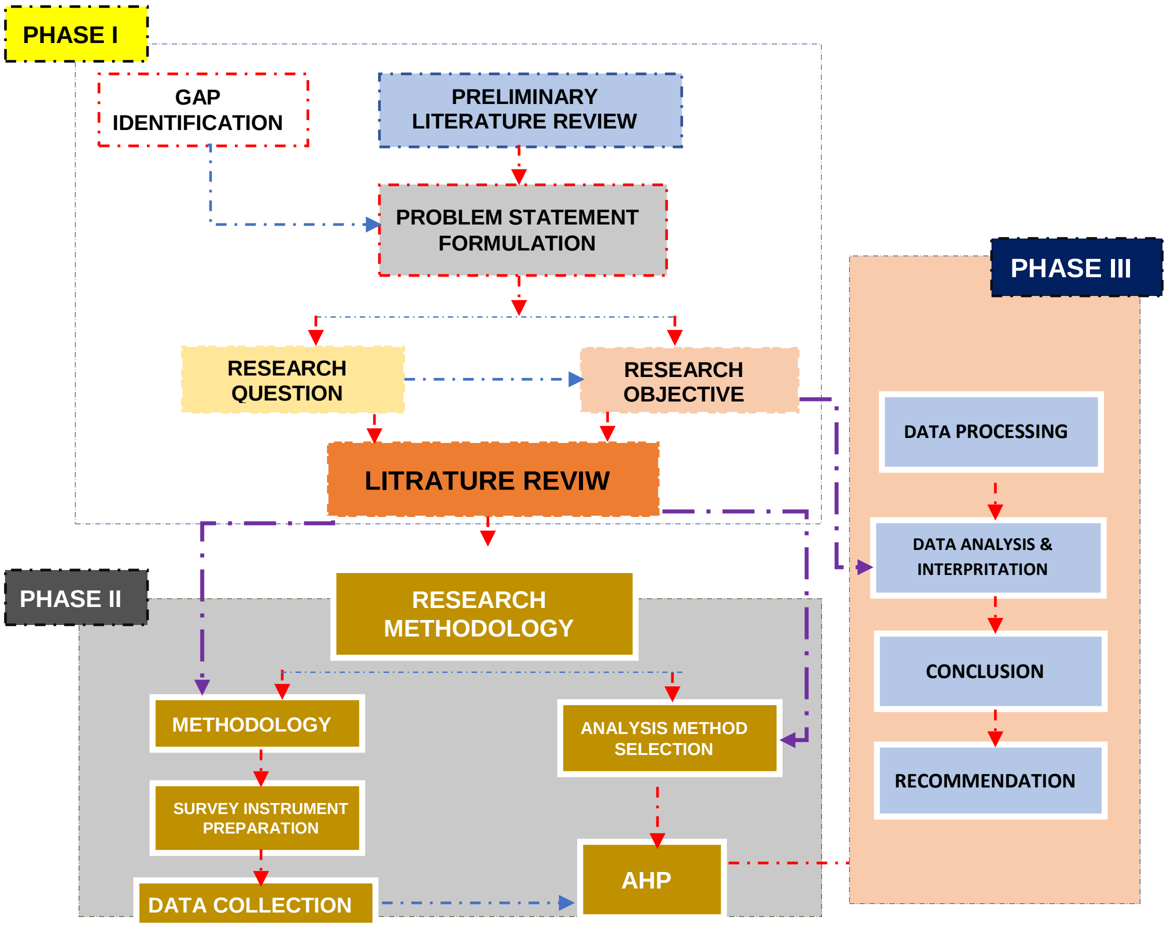

Figure 1: Steps of Research Design

3.5. Phases of the Research Process

In general, the research process is divided into two phases. Through an in-depth and systematic literature study, the first phase comprises an exploratory search for relevant data from secondary data sources related to the critical success criteria for IBS implementation. The second phase, on the other hand, is concerned with the process of collecting primary data through the use of survey instruments such as survey interviews and questionnaires.

3.5.1. The Exploratory Phase

To achieve the goal of this paper, all relevant literatures on CSFs as mentioned by various researchers were systematically reviewed in the first stage in order to collect and obtain detailed evidence for the impact of the important factors, and the review also assisted in understanding the current issues and gaps that exit on the theme, thereby furthering the identification of the CSFs variables to be used in the design of the survey instrument. The scope of the review includes publications from journals articles, conference proceedings, reports as well as thesis and books.

Temporal scope, the resources reviewed spanned from 1999 to 2020 in order to cover a wide timeframe while still collecting emerging developments.

The literature review is primarily concerned with identifying potential critical success factors (CSFs) for the Industrialized Building System (IBS). A literature review attempts to characterize, summarize, categorize, and clarify the contents of information gathered during the process.

The systematic review method has been chosen based on research by (Xiao Y. and Watson, M., 2017), which outline the six essential steps of conducting a systematic review.

Step 1: Identifying Keywords for Review: Keywords relevant for the systematic review were identified. A total of 6 most appropriate keywords were identified and used to fulfill the requirement of the study. The 6 keywords are “IBS”, “Industrialized Building System”, “pre-fabrication”, “modern method construction”, “off-site construction”, and “industrialized building system (IBS)”.

Step 2: Preliminary Search: Search was done using all the keywords obtained from the first step. The search was made based on the subject area of engineering as IBS is mainly an engineering method of construction innovation. Goggle® search engine is used to generate search results from keywords identified in previous step. In Scopus, the search is conducted from March,2020-July,2021 considering ‘Title/Abstract/Keywords’ and a total of 127 documents are generated during the process.

Step 3: Assessing the Quality of the Studies: Results generated through step 2 were further filtered to obtain the most suitable articles in order to achieve the objective.

Step 4: Selecting Data Source: Specific data source was selected from the 127 documents generated from step 2. Total of 83 documents were selected to be synthesized to obtain factors that influence performance of IBS project.

Step 5: Summarizing the Evidence: All 83 total filtered documents were then synthesized and grouped into themes consisting of what factors were the articles mostly mentioned or highly discussed. From total of 83 articles, 44 correspond towards factors influencing IBS project performance. The remaining 39 articles were studies that were not directly related towards IBS project performance.

Step 6: Interpreting Findings, Includes Synthesizing: Articles obtained were then interpreted and synthesized. As a result, 31 factors were classified and categorized in to 8 main factor categories under the theme of ‘critical success Factors influencing IBS Implementation. The 31 factors were then described in detail of what and how does the factor itself influence implementation of IBS.

Table 3: Critical Success Factors Coded for Analysis

CATEGORY	CRITICAL SUCCESS FACTORS(CSF)	CODE	CATEGORY	CRITICAL SUCCESS FACTORS (CSF)	CODE
KNOWLEDGE FACTOR (CSF i1)	Training & Education	**(CSF 1)**	**PRODUCTION AND LOGISTICS (CSF i8)**	Facilities (Level of Automation)	**(CSF 16)**
	Labour skill	**(CSF 2)**		Transportation	**(CSF 17)**
	Skill of Expertise	**(CSF 3)**		Modularization(Standardization)	**(CSF 18)**
				Factory Location	**(CSF 19)**
TECHNOLOGY FACTOR (CSF i5)	Utilization Of Software	**(CSF 4)**		Production Capacity	**(CSF 20)**
	Information Communication Technology (ICT),	**(CSF 5)**			
INTEGRATION FACTOR (CSF i7)	Integration Of Resources	**(CSF 6)**	**COST FACTOR (CSF i4)**	Initial Investment Cost	**(CSF 21)**
	Team Integration	**(CSF 7)**		Operational Costs	**(CSF 22)**
	Integrated Processes Assessment	**(CSF 8)**		Cost Estimation Models	**(CSF 23)**
GOVERNMENT POLICIES AND REGULATION (CSF i6)	Policy Framework	**(CSF 9)**	**MANAGEMENT FACTORS (CSF i3)**	Good working collaboration	**(CSF 24)**
	Regulations	**(CSF 10)**		Effective Communication Channel	**(CSF 25)**
	Standard /Modular Coordination /	**(CSF 11)**		Team Members Involvement During the Design Stage	**(CSF 26)**
				Risk management	**(CSF 27)**
SUPPLY CHAIN AND MARKET FACTOR (CSF i2)	Management of supply chain and logistic	**(CSF 12)**		Extensive Planning and Scheduling	**(CSF 28)**
	Procurement Management	**(CSF 13)**		Top-down commitment	**(CSF 29)**
	Business and Marketing strategy	**(CSF 14)**		On-Site Management	**(CSF 30)**
	Payment Issues	**(CSF 15)**		Technical Factor	**(CSF 31)**

3.5.2. The Primary Data Collection Phase

Primary data is collected in the second step using two survey tools. Questionnaires is issued to professionals, institutions, and prefabricated materials manufacturers who have experience working on IBS-related projects based on pre-determined selection criteria, and semi-structured interviews is conducted.

3.6. Sample Size and Sampling Technique

Non-probabilistic purposive sampling is used to identify industries and professionals involved in the manufacturing of prefabricated construction materials. According to Bartlett, (2001), researchers should use a 50% estimate of P to minimize variance and give the largest possible sample size (Bartlett, 2001). The required sample size is calculated using a single population proportion formula. The calculation is based on a 95% confidence level with a 5% margin of error. There are several statistical formulae available for calculating sample size. There are various techniques for computing the sample size for categorical data, each employing a distinct formula.

Table 4: Sample Size Determined by Desired Accuracy and Confidence Level *(Gill, 2010)*

$n = \frac{p\,(100-p)z^2}{E^2}$	**population Variance of P= 50%**		
	Confidence level = **95%**		
Margin of Error	**5**	**3**	**1**
Population Size	**44**	**48**	**50**

Where N Is the Sample Size Required

P Is the Percentage Occurrence of a State or Condition

E Is the Maximum % Error Required

Z Is the Value Corresponding to Level of Confidence Required

Sample Size Determined by Desired Accuracy and A Confidence Level Of 95%Source: **(Gill, 2010)**

The sample size is a total of 44 respondents. The respondents comprised of professionals, contractors, consultants, manufacturers, construction material importers and project owners.

3.7. Data Collection Instruments

For data collection a questionnaire and interview survey instrument are prepared, in this way, respondents determine the most important factors and then specified degree of importance (priority) of selected factor based on a 9-point scale shown on Table 8 and explained with the questionnaires form attached in annex 2_a-2_d.

Through the semi-structured interview attached at annex 1 the respondents address the questions forwarded form the questions during a face-to-face interview session. The interview questions are open-end questions and designed to triangulate and assure the validity of data obtained from the questionnaires survey for both research questions. The questionnaire consisted two main parts. Part A was designed to gather some general information and background on the respondents, followed by part B, which was designed to gather data on the importance of the critical success factors identified through literature (see Table 3). The data to be collected using questionnaires instruments is designed to obtain data to answer Both research question, which is formulated to identify and prioritize the critical success factors for the implementation of IBS precast concrete for mass housing projects in Addis Ababa. The questionnaires are prepared in a stratified manner to target the best potential respondents for the 8 indicators and handed over to the respondents for their responses.

3.8. Data Source and Collection Methods

The data collection and analysis were based on the culmination of interviews and questionnaire surveys. The study population consists of construction professionals both in public and private sectors namely, architects, builders, civil engineers and construction managers, contractors, consultants and project owners. The main reason for the selection of the sample is based on the highly involvement of this professionals in the construction sector particularly on projects that utilize IBS system for construction.

Table 5: Data Source criteria for Professionals and Expertise

	Level Of Education	Experience In the Construction Sector	Exposure To the IBS	Sample Size
Architects	Degree & above	Minimum of 10 years	Should have a previous exposure	5
Construction Engineers	Degree & above	Minimum of 10 years	Should have a previous exposure	5
Construction Managers	Degree & above	Minimum of 10 years	Should have a previous exposure	5

Table 6: Data Source Criteria for Institutions and Companies

	Experience in the construction sector	Exposure to the IBS	Sample Size
Contractors	Minimum of 15 years	Should have a previous exposure	5
Consultants	Minimum of 15 years	Should have a previous exposure	5
Project owners	Minimum of 15 years	Should have a previous exposure	5
Government officials	Minimum of 15 years	Should have a previous exposure	5

Table 7: Data Source Criteria for Manufacturers and Importers

Ownership	Period of involvement	Diversity of products	Sample Size
Government	Minimum of 5 years	Minimum of 3 type of components	3
Private	Minimum of 5 years	Minimum of 3 type of components	3
Importers	Minimum of 5 years	Minimum of 3 type of components	3

3.9. Data Analysis Method

3.9.1. The Analytic Hierarchy Process (AHP)

The critical success factors are identified and prioritized using the analytic hierarchical process. AHP is one of the most often used multi-criteria decision-making techniques (Saaty T. , 1980). It solves difficult issues by breaking them down into smaller chunks and organizing them into a hierarchical framework. The AHP is a decision-making tool that can be used to solve difficult decisions. Objectives, criteria, sub-criteria, and options are organized in a multi-level hierarchical framework. When faced with multidimensional and multi-criteria judgments, this strategy would be used.

Developed criteria can be both quantitative and qualitative. This method is based on pair-wise comparison and the decision maker starts the operation by forming the hierarchy tree. The levels of comparable under estimate variables and comparative alternatives are represented in a hierarchical tree, followed by a series of pair-wise comparisons. These comparisons define the weight of each component in relation to other factors, and the logic of the hierarchical process, in turn, integrates the acquired matrixes to arrive at the best decision.

AHP analysis method is adopted as an analysis tool for this research since, the method allows categorizing the different criteria and factors in to sub-categories and can generate a pairwise comparison of each factor which eliminates a subjective bias in decision making during prioritization to reach at optimal result of the analysis. AHP is also applicable for the analysis of both qualitative and quantitative data, which is the research approach adopted in this research. The method also assures the validity of the analysis with a consistency Index that can be generated from matrix calculation explained in the steps of AHP presented below.

Steps of the AHP are as follows:

Step1: Define and clearly state the objectives of the complex and complicated problem.

Step2: With the use of a group decision or survey approach, the multidimensional problem is reduced into a hierarchal structure.

There are several levels to the hierarchical structure. The problem's objective is indicated by the top-level hierarchy. In the following level, this aim is subdivided into numerous criteria. The criteria are then broken down into sub-criteria levels, which illustrate the specifics of each one. This breakdown of the hierarchy continues until no more sub-criteria decomposition is feasible.

Step3: The generation of normalized matrix and determining the priority level of the components is the third stage in AHP. By dividing each column value of the comparison matrix formed in the second stage into the sum of related columns individually, a normalized matrix is obtained. The average value of each row is counted after the value for each row is summed using a normalized matrix. The priority vector is the outcome, and it represents the relevance level (rating) of the criterion on the row.

Step4: The fourth step of AHP involves determining whether or not the matrixes are consistent. The major goal is to see how well the important values (relative priority) represent reality.

Matrix consistency is required for AHP to be considered valid. The defined importance level for each element in the third stage and the comparison matrix of related columns established in the second stage are multiplied and summed to determine whether the matrix is consistent, and the rate vector is obtained. Consistency index (I.I) is calculated as

$$I.I. = \frac{\lambda_{max} - n}{n-1}$$

The largest eigenvalue of the pair-wise comparison matrix λ_{max}, where n is the matrix's rank, and random index (I.R.) which is the I.I. of the randomly generated matrix. For different matrix size (n), the respective values of I.R. are depicted in Table 8. After that, Consistency Rate must be calculated in order to see whether decision maker was consistent during making comparison or not (Saaty R. , 1987). Consistency ratio (I.R) is calculated with;

$$I.R = \frac{I.I.}{I.I.R.}$$

A decision maker who is entirely consistent should always get CI=0, although modest amounts of inconsistency can be tolerated. In particular, if

The inconsistencies are acceptable, and a reliable result may be expected from the AHP if CI<0.1 (Saaty T. , 1980).

$$\frac{CI}{RI} < 0.1$$

Table 8: Values of the Random Index (RI)

n	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
I.I.R.	0.0	0.0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.45

Source: (Saaty T. , 1980)

For the sake of ease of analysis and generating a qualified presentable analysis result or output, analysis software called **Expert Choice**® is used during the analysis of data collected from the survey instruments.

Table 9: Fundamental Scale for pairwise comparison/ Saaty's scale/

Intensity of Importance	**Definition**	**Explanation**	**Reciprocal**
1	Equal importance	Two elements contribute equally to the objective	**1**
3	Moderate Importance	Experience and judgement moderately favour one element over the other	**1/3**
5	Strong Importance	Experience and judgement Strongly favour one element over the other	**1/5**
7	Very strong Importance	One element is favoured very strongly over another	**1/7**
9	Extreme Importance	one element favouring highest possible order over another	**1/9**
2,4,6,8	Intermediate values b/n the two judgments	When compromise is needed	**1/2,1/4,1/6,1/8**

Source: **(Saaty R. , 1987)**

3.9.2. Analysis for Potential Advantages of IBS

The data collected from questionnaire survey to rank the potential advantages of IBS is analyzed using a simple statistical calculation to obtain response rate of 37 respondents. The result of the analysis is interpreted in percentile from the total survey participants' response to rank five potential advantages identified.

3.10. Cost Analysis

The cost analysis addresses the cost wise comparison of conventional (site intensive construction) method vs. construction method that utilize the IBS precast components for a specific structure to show the advantage of the IBS method in terms of its cost saving compared to the prior method.

In this particular analysis, cost breakdown for both systems are gathered and analyzed for the direct cost incurred for the whole process and time value of money analysis will be computed.

The source of relevant data, like market value and cost of material is used during study period. For the IBS system the production and transportation related cost will be collected for exiting manufacturers' source.

In order to compare the cost of both construction technique, the actual direct cost that the building incurred of the precast structural elements that includes slab, column, beams and staircase of the building will be analyzed or calculated using PBPPE's design and cost breakdown templates, whereas for the in-situ construction method the cost breakdown is done using price rate from BOQ. For the sake of comparison, the total floor area (m^2) and number of floor (total story) will be similar. For both Construction techniques the total cost, and construction cost per m^2 is generated and time value of money is computed.

The cost estimation used is Bottom-up estimate using unit costs for bill of quantities, the method is used, since it is a simple method and widely used in Ethiopia. It includes breaking down the construction project into measurable tasks and activities and assigning unit costs to them. These are tasks that would have to be completed for the completion of the structural works. Then, these tasks are quantified and each of their quantities are multiplied with their corresponding unit costs. The sum of their products gives the total direct cost. The estimate is a design estimate or conceptual estimate – using a conceptual design of a specific building design using both methods of construction.

The formula used for unit cost calculations is a widely used Formula Based on Labor, Material and Equipment.

Formula (Hendrickson, 2008)

$$y = \sum_{i=1}^{n} y_i = \sum_{i=1}^{n} Q_i (M_i + E_i + W_i L_i)$$

Where

$\mathbf{Q_i}$ = work
$\mathbf{M_i}$ = unit material cost
$\mathbf{E_i}$ = unit equipment rate
$\mathbf{L_i}$ = units of labour per unit of Qi
$\mathbf{W_i}$ = wage rate per Li for task ‘i

3.11. Reliability and Validity

3.11.1. Research Reliability

To ensure validity and reliability of the research, variables are comprehensively defined, this also helps to reduce misunderstandings thus increase the reliability of the survey instruments. In addition to achieve data reliability, all the respondents participated during data collection process are profiled and presented during the analysis stage. A record of the responses is recorded specially for the interview process with the consent of the participant.

Moreover, triangulation of results is employed to ensure reliability of the data collected. Thus, all the data acquired from different sources is compared and cross checked, whereas both instruments are used to address the same question (control question) to check the consistency of the response from the same respondent. Besides, to ensure reliability of the data, the questionnaires were tested prior to distribute to the intended respondents. The questions then amended based on the comment collected from those who participated in the test.

3.11.2. Research Validity

The validity of the data is also acquired through careful selection and use of appropriate size of the sample. For triangulation, two data collection approaches are used in combination.

The AHP incorporates an effective technique for checking the consistency of the evaluations made when building each of the pairwise comparison matrices involved in the process. The technique relies on the computation of a suitable consistency index, and a perfectly consistent decision maker should always obtain CI=0 (Saaty T. , 1980).

CHAPTER FOUR

4. ANALYSIS AND RESEARCH RESULT

4.1. Introduction

This chapter focuses on analyzing and interpreting the data collected from questionnaires and interviews. Based on the information obtained from the respondents, the findings reported here are an analysis of aggregate data presented in accordance with the research objectives and research questions. For a clear comprehension of these results and analyses, a brief overview of the study is presented at the outset, followed by an introduction to general characteristics of research respondents. Following that, there will be a presentation and analysis of the data pertaining to the research topic.

The analysis is divided into two main sections, each classified according to the study questions. The first section is an analysis performed with AHP to prioritize the critical success factors identified during the research process. The information is analyzed using data from the questionnaire survey as well as information from personal interviews with respondents; the second part discusses a cost benefit analysis of the IBS system compared to conventional construction methods.

4.2. Survey Data Respondents Profile

The study's sample size was 44 systematically selected respondents. Respondents were chosen based on specified criteria for each of the sample categories described in Chapter 3. This decision was made based on criteria such as number of years of experience, technical expertise, and familiarity with IBS. Following that, a total of 44 questionnaires were issued to carefully selected members and stakeholders, who were divided into three groups, based on their prior exposure to IBS precast construction techniques. The questionnaire set was distributed to respondents together with a cover letter explaining the objective of the study and assuring anonymity.

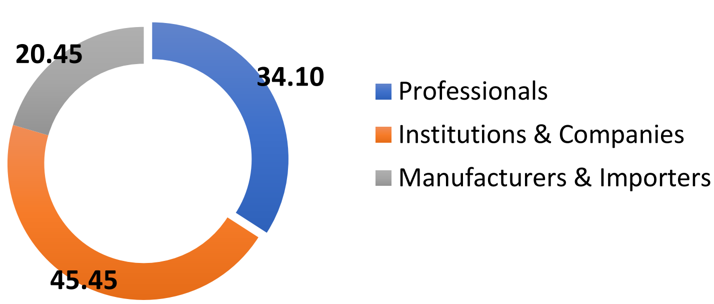

Figure 2: Respondents Proportion (%)

The respondents were chosen based on two criteria: first, they must have more than five years of hands-on experience in the construction sector, and second, they must have participated in projects that have used IBS as a construction method wholly or partially. All respondents came from one of three groups of people who will be involved in implementing IBS. They are also actually Project Owners, Consultants, Contractors, and other experts. Figure 2 depicts the demographic information of the respondents.

4.3. Respondents Response Rate

Out of the total number of sampled respondents (44), a total of 36 complete questionnaires were collected, translate into 82 % response rate. The response rate was considered appropriate when the response rate is above 75% (Nultly, 2008). The rate of return of questionnaire was computed as follows.

Table 10: Respondent's Profile and Rate

Category	Respondents	No. of interview	No. of Qustio. Distributed	No. of Qustio. Collected	Response Rate	Total
Professionals	*Architects*	3	5	5	100%	15/15 (100%)
	Construction Engineers	3	5	5	100%	
	Construction Managers	3	5	5	100%	
Institutions & Companies	*Contractors*	3	5	4	80%	17/20 (85%)
	Consultants	3	5	5	100%	
	Project owners	3	5	3	60%	
	Government officials	3	5	5	100%	
Manufacturers & Importers	*Government*	1	3	1	33%	4/9 (45%)
	Private	2	3	2	66%	
	Importers	1	3	1	33%	

4.4. Data Recording Procedures

The questionnaires were distributed to the participants, who were asked to evaluate the importance of each CSF indicator to the importance of each criterion under each indicator to the importance of the other at the same indicator. Table 9 shows the scale that was utilized in this survey. Following the collection of critical success factors for implementing IBS, data analysis is performed using Expert Choice® software. The software is chosen, since it incorporates intuitive graphical user-friendly interface, automatic calculation of priorities and inconsistencies and several ways to process a sensitivity analysis.

The face-to-face interviewing process was divided into two stages. The interview was sent to the participants prior to the actual interview, and predefined questions were asked wherever they were deemed pertinent to the topic, and the responses were recorded. Following that, factory tours were conducted to have a thorough understanding of the manufacturers' production processes. Individual and company names of participants were also coded to protect anonymity and organization.

4.5. Data Analysis Procedures

Both Qualitative and quantitative data were collected. The qualitative data were gathered based on interviews. The nature of the data collected from open-ended predefined questions is used to validate the result from questionnaires, where the response is coded in order to divide the information into themes or categories and analysis and interpretation made. Therefore, data organized and sorted by the frequency in which themes are repeated. The data were analyzed using the content analysis method once the decision hierarchy was designed. The quantitative data was analyzed using Expert Choice Comparison. The stages shown below were used to investigate generic decision-making.

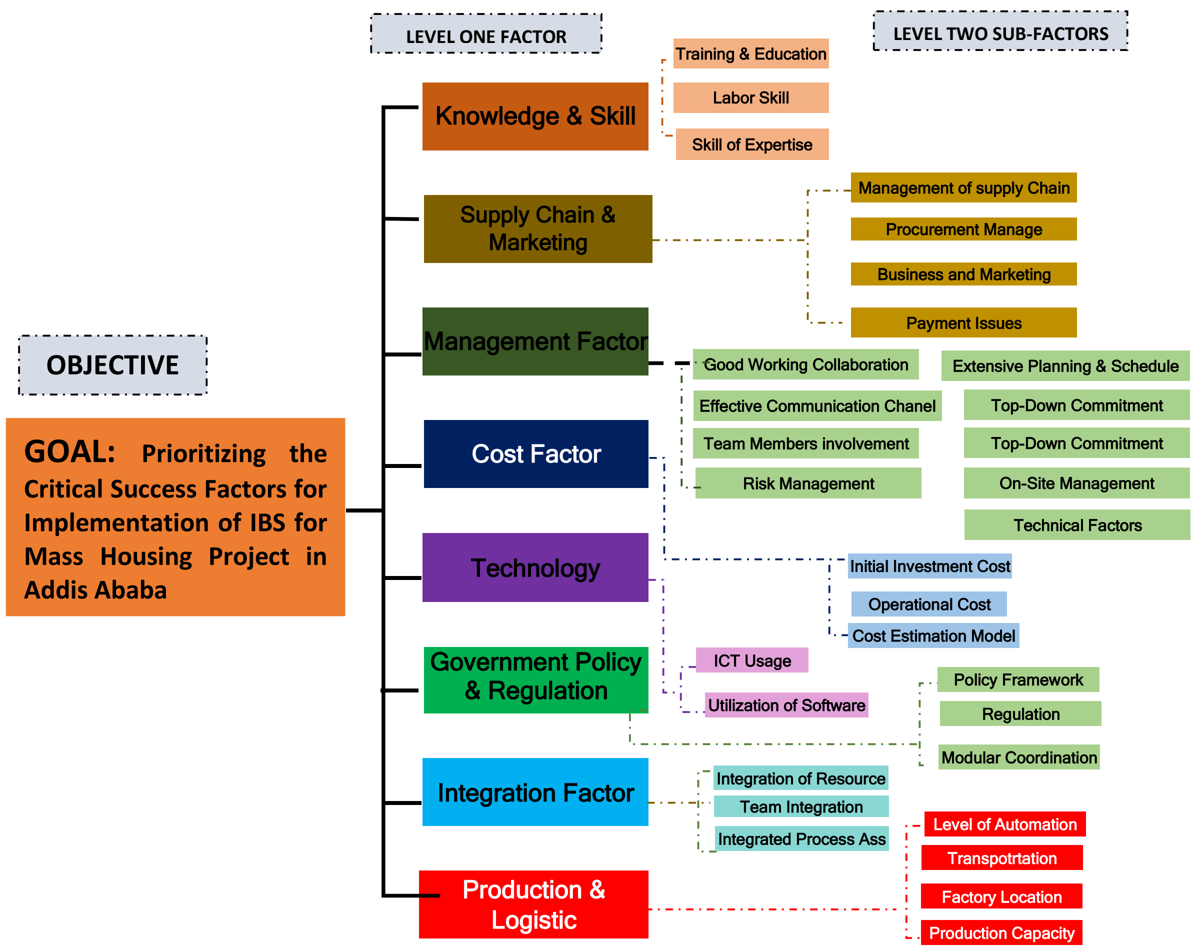

Figure 3: The Analytical Hierarchy Process structure

Step1. ***AHP Structure Development***: primarily, the AHP decision model was structured into objectives, level-one factors and alternatives to weigh the relevant factors and the alternatives as shown in Figure 3 above.

Step2. ***Normalized Matrix Development:*** The pairwise comparison was carried out with 44 selected experts using ECC to define priority vectors at level-one and level-two factors. Then, to determine here the final details of priority, a numerical evaluation and normalization were performed based on the assessment of the level of importance.

Table 11: *Example of comparison Matrix*

INDICATORS/ CATEGORY	Knowledge Factor	Technology Factor	Integration Factor	Government Policies & Regulation	Supply Chain & Market Factor	Production & Logistics	Cost Factor	Management Factors
Knowledge Factor	1	3	5	7	3	5	2	1/3
Technology Factor	1/3	1	3	1/3	2	1/5	1/3	2
Integration Factor	1/5	1/3	1	1/5	1/5	3	4	1/3
Government Policies & Regulation	1/7	3	5	1	9	7	1/3	7
Supply Chain & Market Factor	1/3	1/2	5	1/9	1	1/3	3	1/5
Production & Logistics	1/5	5	1/3	1/7	3	1	9	3
Cost Factor	12	3	1/4	3	1/3	1/9	1	1/7
Management Factors	3	1/2	3	1/7	5	1/3	7	1

Step3. ***Data encoding in to the Software (Expert Choice***®): recording the data obtained from coded participants in to the software for analysis.

Model Name: IBS

Compare the relative importance with respect to: Goal: Prioritizing Critical Success Factors For Successful implimentation of IBS for Mass Housing In Addis Ababa

Circle one number per row below using the scale:
1 = Equal 3 = Moderate 5 = Strong 7 = Very strong 9 = Extreme

1	CSF i1	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	CSF i2
2	CSF i1	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	CSF i3
3	CSF i1	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	CSF i4
4	CSF i1	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	CSF i5
5	CSF i1	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	CSF i6
6	CSF i1	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	CSF i7
7	CSF i1	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	CSF i8
8	CSF i2	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	CSF i3
9	CSF i2	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	CSF i4
10	CSF i2	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	CSF i5
11	CSF i2	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	CSF i6
12	CSF i2	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	CSF i7
13	CSF i2	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	CSF i8
14	CSF i3	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	CSF i4

Figure 4: Data Entry Format on Expert Choice Software

Step4. *Checking for respondents Consistency:* The fourth stage of AHP analysis is, to determine whether the matrixes are consistent. The major purpose is to determine how well the relative priority conforms to reality. Matrix consistency is required for AHP to be considered valid. To evaluate if the matrix is consistent or not, the defined importance level for each element in the third stage, as well as the comparison matrix, must be entirely consistent, and the decision maker must always obtain CI=0, however modest degrees of inconsistency may be accepted. In particular, if Taking n=8, since the level on factors are 8 in number and **I.I.R 1.41** as shown in Table 8. $\frac{CI}{RI} < 0.1$

Step5*. Sensitivity Analysis:* The sensitivity analysis is the final step in the decision-making process, in which the input data is altered slightly to examine how it affects the results. If the ranking does not change, the results are considered robust. The best way to do a sensitivity analysis is to use an interactive graphical interface. Expert Choice allows for a variety of sensitivity tests, with the key distinction being the numerous graphical representations.

4.6. Analysis output form AHP Prioritization and Discussion

4.6.1. Priority Ranking of the CSF

As listed in Table 12 the eight critical success factors identified in the literature investigations is prioritized according to their priority vector resulted from respondents' data analysis.

Table 12: *Ranking of the Eight CSF*

Code	The Eight CSF (Level One)	Priority Vector (%)	Priority Ranking
CSFi_1	Knowledge and Skill Factor	14.4	2nd
CSFi_2	Supply Chain & Market Factor	10.9	5th
CSFi_3	Management Factors	10.4	6th
CSFi_4	Cost Factor	19.1	1st
CSFi_5	Technology Factor	11.8	4th
CSFi_6	Government Policies & Regulation	13.8	3rd
CSFi_7	Integration Factor	9.6	8th
CSFi_8	Production & Logistics	10.0	7th

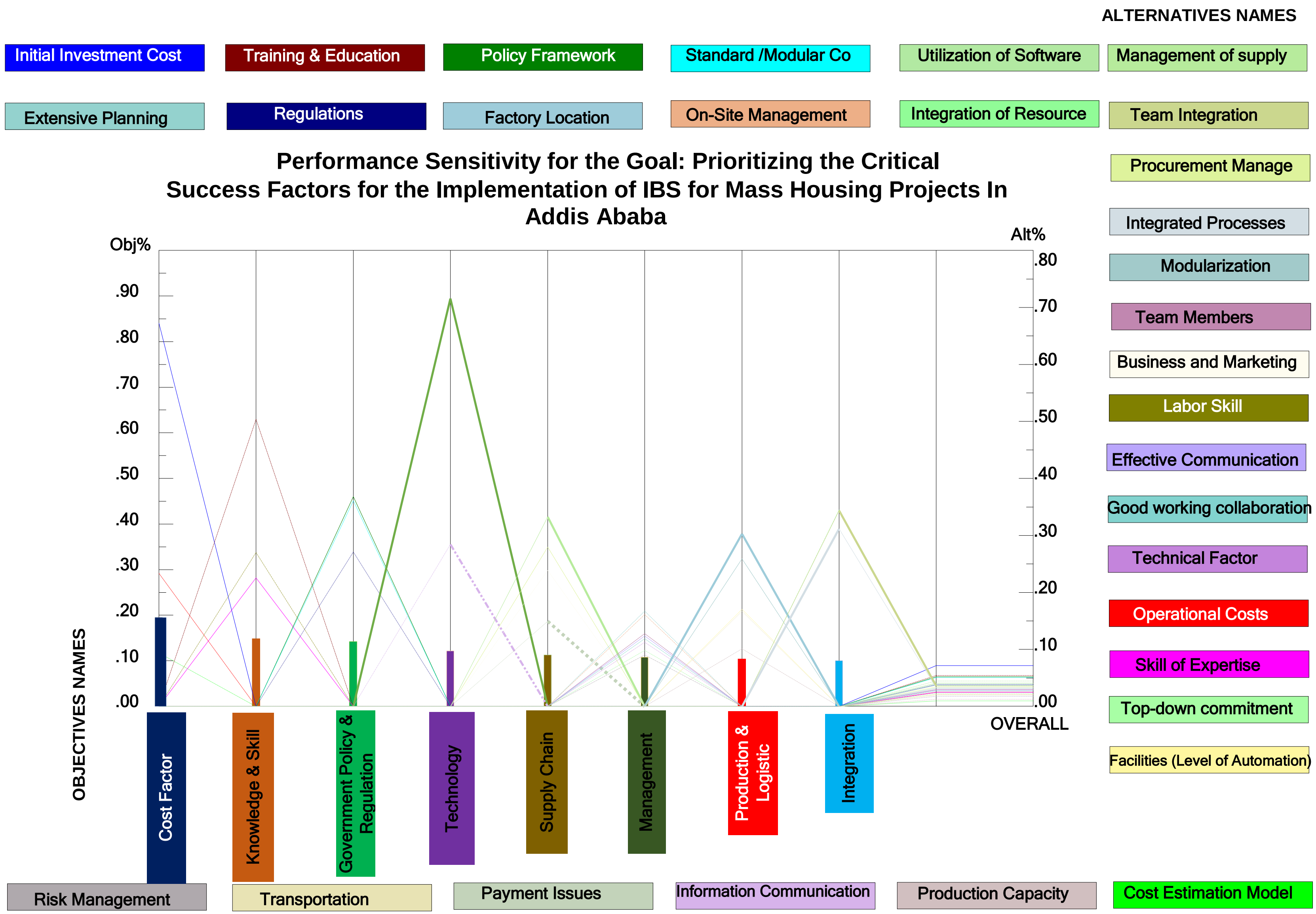

Figure 5: Priority analysis of the eight CSFs IBS with respect to the level-one and level-2 decision-factors

4.6.1. Analysis of the AHP Results

The analysis put the cost factor as the most critical factor for a successful implementation of IBS for mass housing project, shown in Table 13 particularly, Initial investment cost, which includes the cost required to erect production facility cost incurred to install Machinery, Equipment and Technology Costs. To achieve a well-organized IBS implementation availability of different source of finance for the involving stakeholders is identified as a critical success factor since the cost is too high and unbearable for investors and contractors, reduction of construction levy for the contractors, a leasing model for buying the machines, financial assistant and tax exemption from the government, and reduction on import duty and sales tax on heavy machineries are considered as critical enabling factors.

Table 13: Pairwise Comparisons and Global Ranking of CSF **/Cost Factors/**

The CSF (Level One) **CSFi_4**	**Code**	**The Local Ranking of Alternative CSFs**	**Priority Ranking** *[pairwise comparisons]*	**Priority Vector (%)**	**Priority Ranking**
		(Level Two)	*(Local)*		*(Global)*
COST FACTOR Priority Vector = 19.1%	**CSF-21**	Initial Investment Cost	**1st**	7.1	**1**
	CSF-22	Operational Costs	**2nd**	2.5	**22**
	CSF-23	Cost Estimation Models	**3rd**	1.0	**31**

Table 14: Pairwise Comparisons and Global Ranking of CSF **/Knowledge Factors/**

The CSF (Level One) **CSFi_1**	**Code**	**The Local Ranking of Alternative CSFs**	**Priority Ranking** *[pairwise comparisons]*	**Priority Vector (%)**	**Priority Ranking**
		(Level Two)	*(Local)*		*(Global)*
KNOWLEDGE FACTOR Priority Vector = 14.4%	**CSF-21**	Training & Education	**1st**	5.4	**2**
	CSF-22	Labour skill	**2nd**	2.9	**18**
	CSF-23	Skill of Expertise	**3rd**	2.4	**23**

Knowledge Factor comes Second in the priority ranking. Due to their contribution to the development process and role in the decision-making process, addressing the knowledge gap and shortage of expertise within the area of IBS implementation including such architects, contractors' / production companies, developers, and practitioners has a significant impact on the success of IBS for innovative modern large scale produced housing projects.

As shown in Table 14, Training and Education about IBS in the education system found to be critical for the implementation of IBS which reinforce the general argument of the high level of specialities is derived from high level of training and professional education. An investment in training to master IBS skills is inevitable and critical to succeed in IBS. Educating professional including architects and engineers in a systematic manner with the fundamental design process to fabricate and assemble the components of IBS in undergraduate engineering programs is mandatory in order to realize the benefits of utilizing IBS to its full potential.

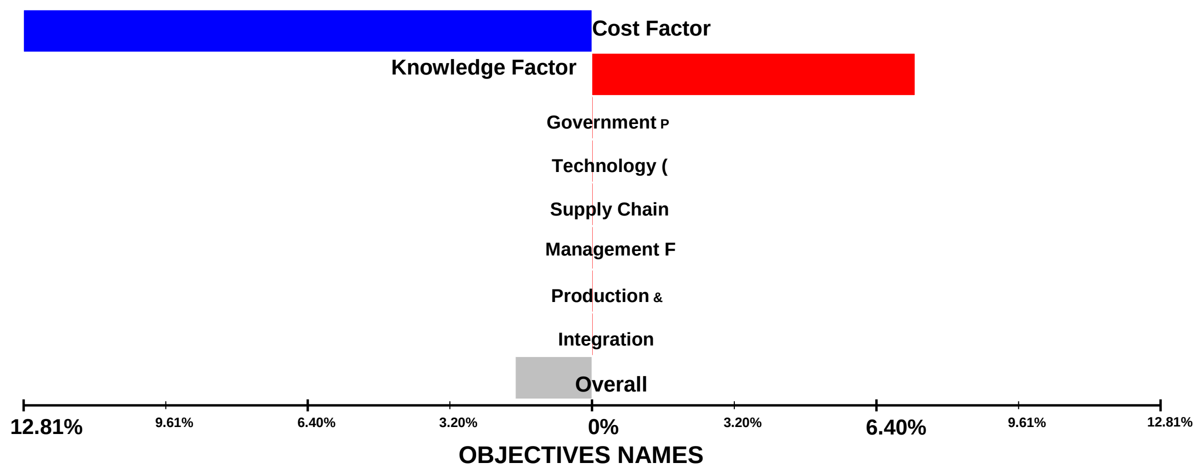

Figure 6: Weighted head-to-head between Initial Investment Cost and Training & Education

A further analysis for head-to-head comparison of these two critical success factors reveals that, educating professionals and developing various skill about IBS is by far the most influential factor compared to the cots factor, shown on Figure 6.

A critical success factor ranked third is a factor related with government policies and regulation as shown in Table 15. This factor is considered as one of the most important factors in enabling the IBS in construction process. Because firms and industries usually align their strategies with government policy, favorable government policy influences the development of new techniques, notably in the construction industry. In addition, participants' response for the interview conducted stressed, for successful IBS implementation governments supportive policy mechanisms for the construction manufacturing industry such as developing capacity and capability of the private sector, strengthening research and development and commercialisation, financial assistant and various regulatory measures are considered as critical enabling factors.

Table 15: Pairwise Comparisons and Global Ranking of CSF **/Government Policies & Regulation/**

The CSF (Level One) **CSFi_6**	**Code**	**The Local Ranking of AlternativeCSFs**	**Priority Ranking** *[pairwise comparisons]*	**Priority Vector (%)**	**Priority Ranking**
		(Level Two)	*(Local)*		***(Global)***
GOVERNMENT POLICIES & REGULATION Priority Vector = 13.8%	**CSF-9**	Policy Framework	**1st**	5.2	**3**
	CSF-11	Standard /Modular Coordination /	**2nd**	5.1	**4**
	CSF-10	Regulations	**3rd**	3.8	**8**

The ability for IBS to thrive could well be hampered by a lack of government incentives and promotions to encourage housing developers to use such innovative building technologies, as well as a lack of local government enforcement of the government's promised incentives to developers. Creating a set of standardized national standards to enable Modular co-ordination for dimensioning areas, components, and fittings, among other things, so that even when the components and fittings are manufactured by different suppliers, all elements fit together without cutting or extending can create a foundation on which the variety of types and sizes of building components can be minimized, where each component is designed to be interchangeable with other similar ones and thus provide the designer with the greatest degree of freedom and choice

Table 16: Pairwise Comparisons and Global Ranking of CSF **/Technology Factors/**

The CSF (Level One) **CSFi_5**	**Code**	**The Local Ranking of Alternative CSFs**	**Priority Ranking** *[pairwise comparisons]*	**Priority Vector (%)**	**Priority Ranking**
		(Level Two)	*(Local)*		*(Global)*
TECHNOLOGY FACTOR Priority Vector = **11.8%**	**CSF-4**	Utilization Of Software	**1st**	4.4	**5**
	CSF-5	Information Communication Technology (ICT),	**2nd**	1.8	**29**

Technology Factors, which ranked in fourth place, play an essential role as a medium or proper method for coordinating operations. In this case, technology may serve as a communication channel between team members, allowing them to better integrate their operations and keep the entire team up to date on design information in order to coordinate precise design and construction processes, costs, and timelines in a project. The effective use of software, in particular, significantly aids communication and coordination between parties, resulting in a successfully integrated project team. In particular, BIM has the potential to promote IBS construction by identifying repetition, resulting in greater cost savings through mass customization.

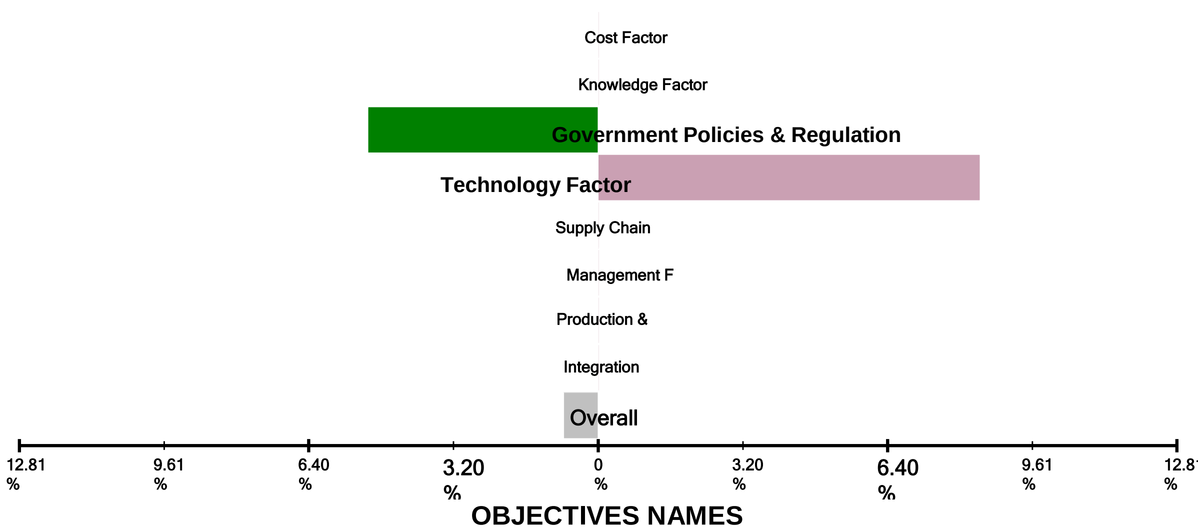

Figure 7: Weighted Head-to-Head between Policy Framework and Utilization of Software

The analysis result shows that software is critical for the implementation of IBS, as shown in Figure 8. Specifically, professionals in the field stress the impact of various Computer aided platforms to eliminate miscommunication, repetition, and revision of design works, because these platforms create a unified data base that streamlines the design team, manufacturing, and distribution processes.

Supply chain &Market Factor and Management Factor is ranked fifth and sixth for IBS implementation success.

Table 17: Pairwise Comparisons and Global Ranking of CSF ***/Supply Chain & Market Factors/***

The CSF (Level One) CSFi_2	Code	The Local Ranking of Alternative CSFs (Level Two)	Priority Ranking *[pairwise comparisons]* (Local)	Priority Vector (%)	Priority Ranking (Global)
SUPPLY CHAIN & MARKET FACTOR Priority Vector = 10.9%	CSF-12	Management of supply chain & logistic	1st	4.1	6
	CSF-13	Procurement Management	2nd	3.4	13
	CSF-14	Business and Marketing strategy	3rd	2.9	17
	CSF-15	Payment Issues	4th	1.8	28

Table 18: *Pairwise Comparisons and Global Ranking of CSF **/Management Factors/***

The CSF (Level One) CSFi_3	Code	The Local Ranking of Alternative CSFs (Level Two)	Priority Ranking *[pairwise comparisons]* (Local)	Priority Vector (%)	Priority Ranking (Global)
MANAGEMENT FACTORS Priority Vector = 10.4%	CSF-28	Extensive Planning and Scheduling	1st	3.9	7
	CSF-30	On-Site Management	2nd	3.7	9
	CSF-26	Team Members Involvement During the Design Stage	3rd	3.0	16
	CSF-25	Effective Communication Channel	4th	2.9	19
	CSF-24	Good working collaboration	5th	2.8	20
	CSF-31	Technical Factor	6th	2.6	21
	CSF-29	Top-down commitment	7th	2.3	24
	CSF-27	Risk management	8th	2.1	26

The IBS requirement for a high level of coordination and integration of supply chains from design, manufacturing, and construction phases influences its performance in terms of supply chain and market factor. A fragmented prefabrication sector, as well as difficulty in establishing efficient coordination among qualified contractors, suppliers, and consultants in the local market who can implement IBS, pose substantial challenges for IBS implementation in developing nations.

In an industrialized building system, management factors are also the niche of the whole supply chain system. According to the study result presented in Table 18, extensive planning and scheduling, as well as on-site management, are the most important influential factors in the implementation of IBS. To guarantee a successful

IBS project, efficient planning and scheduling might ensure that all stakeholders are aware of their respective responsibilities. In order to improve project performance, coordination, scope control, and ensure a smooth project sequence, extensive planning and scheduling of tasks in advance is crucial.

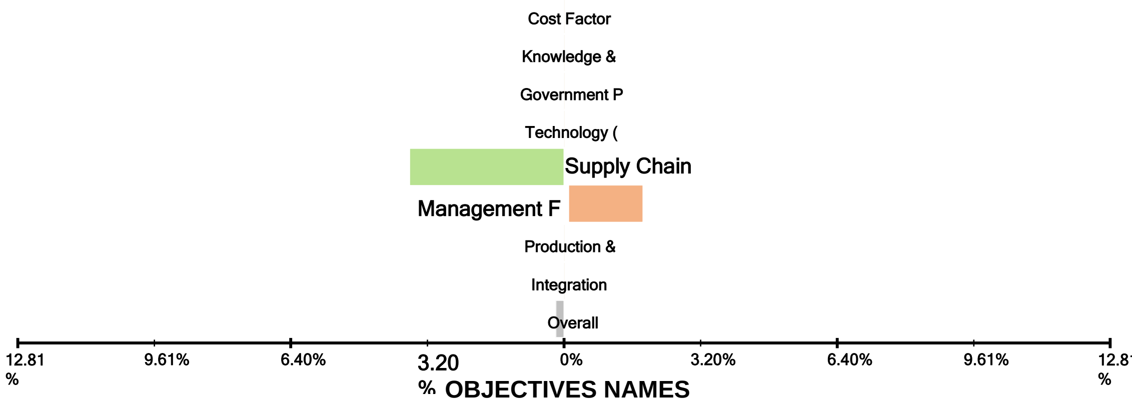

Figure 8: Weighted head-to-head between Management of supply chain & logistic and Extensive Planning & Scheduling

The pairwise comparison of the above factors shows, the management factors affect IBS implementation more compared to Supply chain and Market factor as shown on Figure 9.

Table 19: *Pairwise Comparisons and Global Ranking of CSF **/Production & Logistics/***

The CSF (Level One) CSFi_8	Code	The Local Ranking of Alternative CSFs	Priority Ranking *[pairwise comparisons]*	Priority Vector (%)	Priority Ranking
		(Level Two)	*(Local)*		*(Global)*
PRODUCTION & LOGISTICS Priority Vector = 10.0%	**CSF-19**	Factory Location	**1st**	3.7	**10**
	CSF-18	Modularization (Standardization)	**2nd**	3.2	**15**
	CSF-16	Facilities (Level of Automation)	**3rd**	2.1	**25**
	CSF-17	Transportation	**4th**	2.1	**27**
	CSF- 20	Production Capacity	**5th**	1.2	**30**

Table 20: *Pairwise Comparisons and Global Ranking of CSF **/Integration Factors/***

The CSF (Level One) CSFi_7	**Code**	**The Local Ranking of Alternative CSFs**	**Priority Ranking *[pairwise comparisons]***	**Priority Vector (%)**	**Priority Ranking**
		(Level Two)	*(Local)*		*(Global)*
INTEGRATION FACTOR Priority Vector = 9.6 %	**CSF-6**	Integration Of Resources	**1st**	3.6	**11**
	CSF-7	Team Integration	**2nd**	3.6	**12**
	CSF-8	**Integrated Processes Assessment**	**3rd**	**3.2**	**14**

The last two factors ranked seventh and eighth form the AHP analysis result are Production and Logistics and Integration Factor respectively as shown on table 19 and 20. Factory location with respect to construction sites is ranked high in the factor priority list. The location of production facility is considered as one of the factors for the successful implementation of IBS.

In relation to the strategic location, it has a significant implication to the cost of constriction. Transportation issues as a result of the location of factory location with respect to the construction site, is one of the challenges in managing IBS construction. The issues normally associated with size and weight limitations, route restrictions and permitting. When it comes to integration factor, Integration of

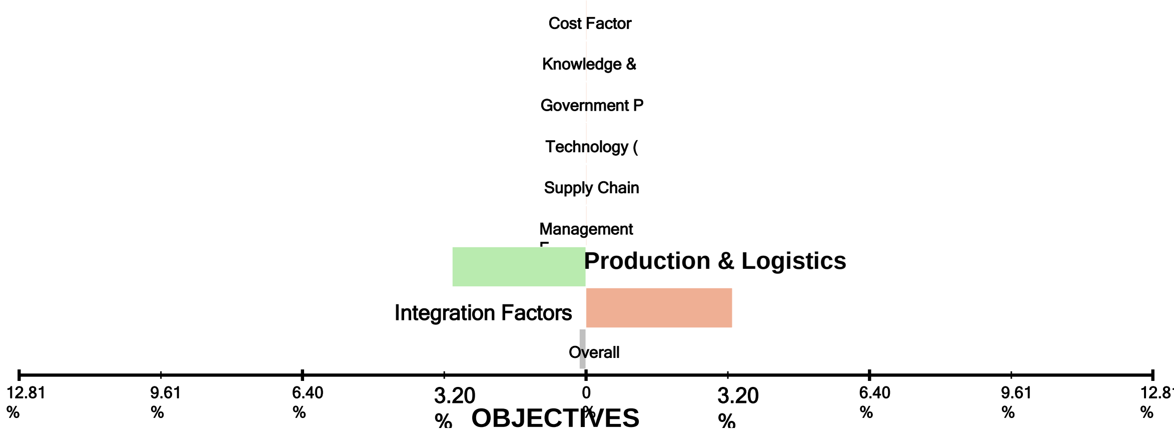

Figure 9: Weighted head-to-head between Factory Location and Integration of Resources

Resources and Team Integration are considered as a critical factor for IBS implementation. The pairwise comparison shows that the production and logistic factor slightly affects IBS performance more than the integration factors as shown on Figure 9.

The overall rank of 8 Critical success factors and 31 alternative factors is summarized and shown on Figure 10 and 11 below.

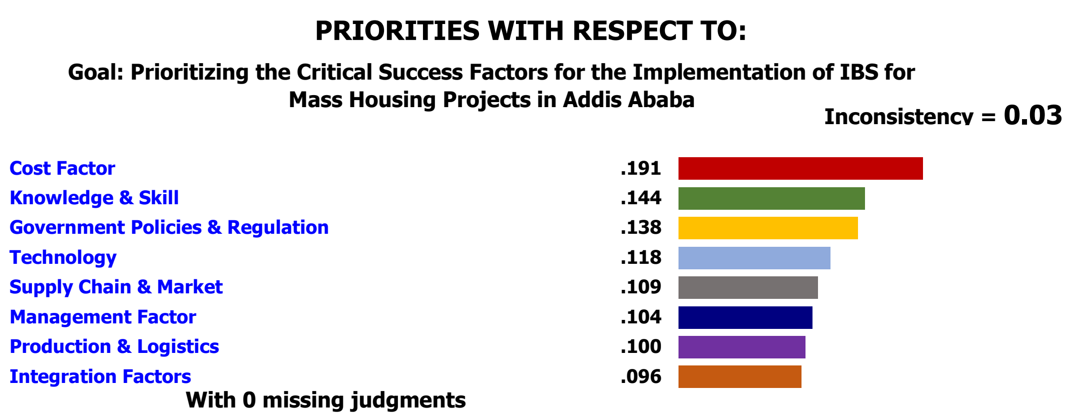

Figure 10: Overall Priority Graph for Prioritized 8 CSFs

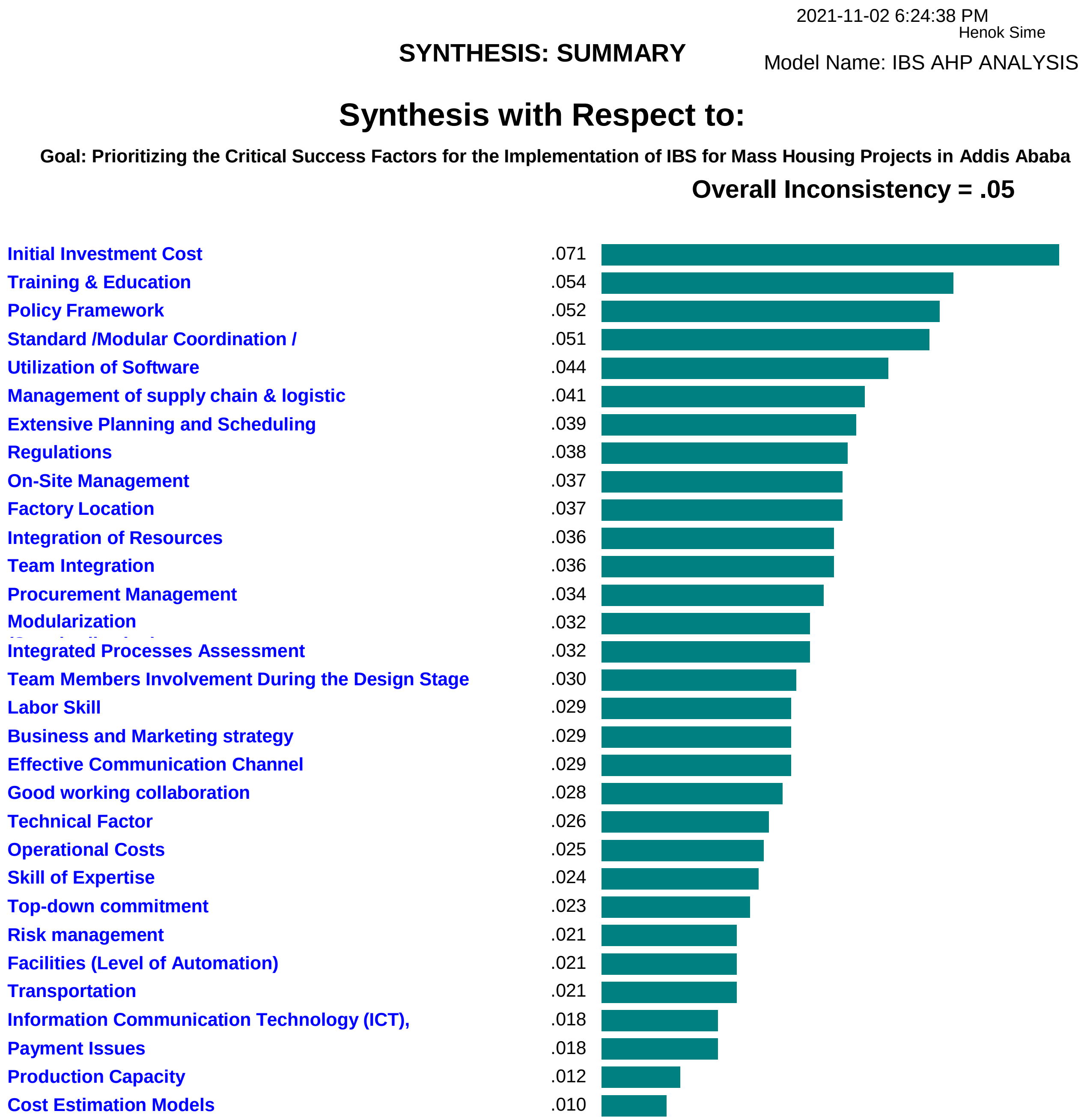

***Figure 11**:* Overall Prioritized 31 CSFs (Alternatives)

4.7. AHP Consistency and Sensitivity Analysis

4.7.1. Consistency of the Analysis Result

The overall consistency of respondents' response is calculated as **0.05** which is less than 0.1, which shows the validity of the analysis result with respect to the objective.

4.7.2. Sensitivity Analysis

The sensitivity analysis is the final phase in the decision-making process, in which the input data is slightly changed to see how it affects the results. The results are regarded to be robust if the ranking does not change. The 'gradient sensitivity' graph is utilized in this study to ensure that the data provided is reliable. The graph depicts the priority of the options with regard to one goal at a time.

The following Gradient sensitivity graph shows the sensitivity of the decision process where the priority vector is modified from the original value and test for the analysis robustness.

Test I: Figure 12 – shifting the priority vector value of COST FACTORS from 19.1 to 21.1 (5 % increase) the priority ranking of CSF is checked against the original priority ranking. The sensitivity test shows the ranking remains similar to the original ranking, the outcome is shown on Figure 15

Test II: Figure 13 – shifting the priority vector value of TECHNOLOGY FACTORS from 11.8 to 12.1 (5 % increase) the priority ranking of CSF is checked against the original priority ranking. The sensitivity test shows the ranking remains similar to the original ranking, the outcome is shown on Figure 15

Test II: Figure 14 – shifting the priority vector value of GOVERNMENT POLICY AND REGULATION from 13.8 to 15.2 (5 % increase) the priority ranking of CSF is checked against the original priority ranking. The sensitivity test shows the ranking remains similar to the original ranking, the outcome is shown on Figure 15

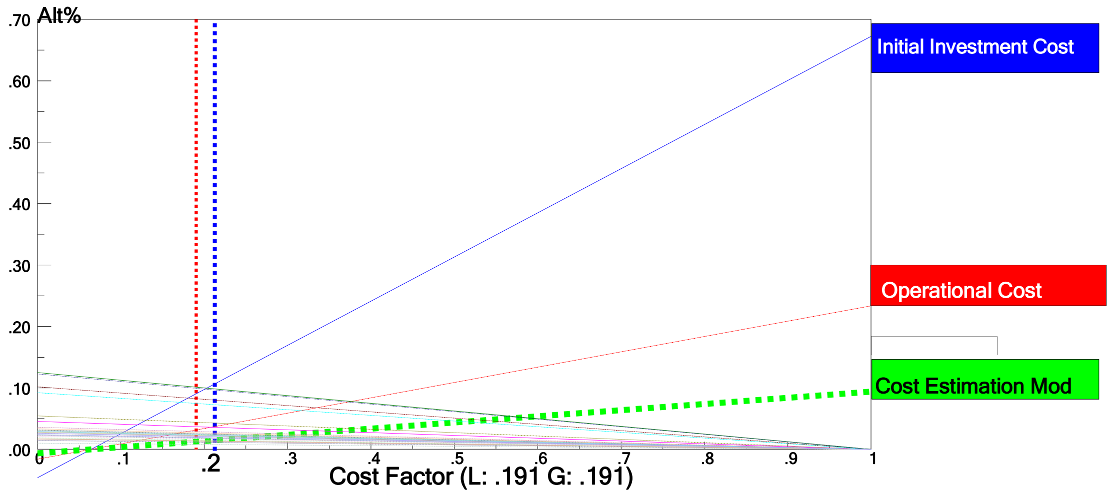

Figure 12: Gradient sensitivity graph for Cost Factor

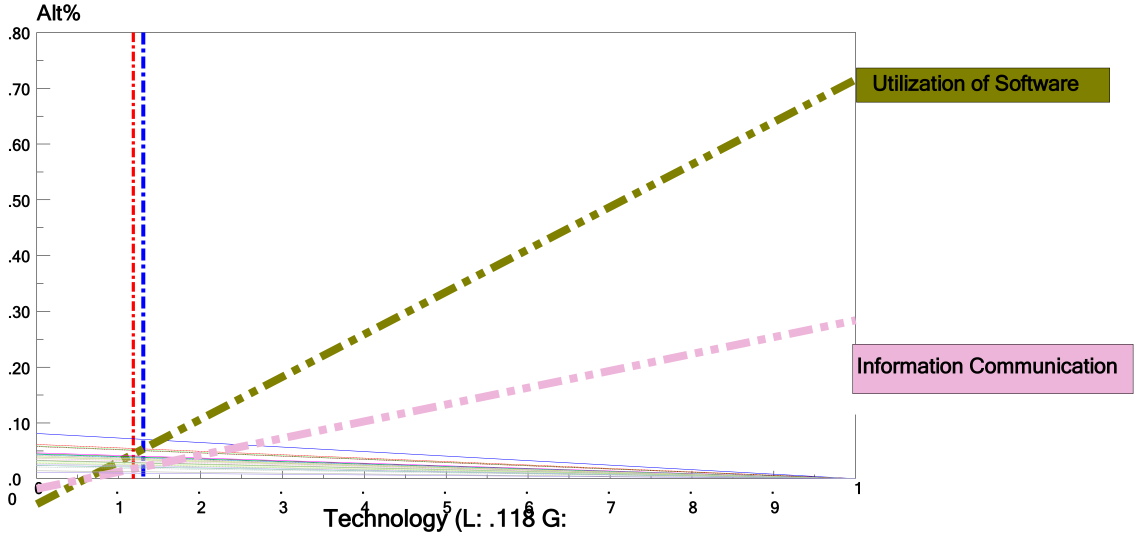

Figure 13: Gradient sensitivity graph for Technology Factor

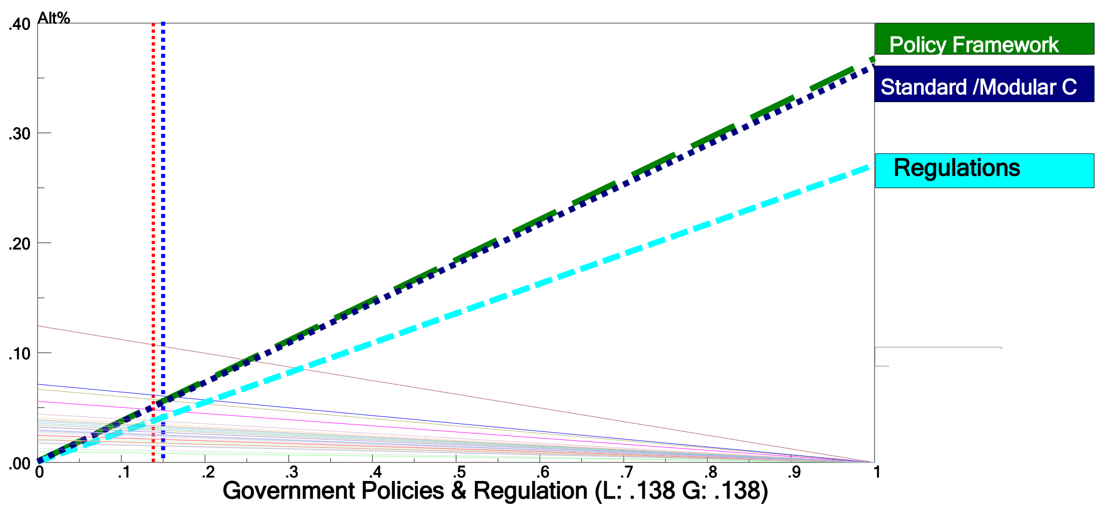

Figure 14: Gradient sensitivity graph for Government Policies & Regulation Factor

Sensitivity Test Result

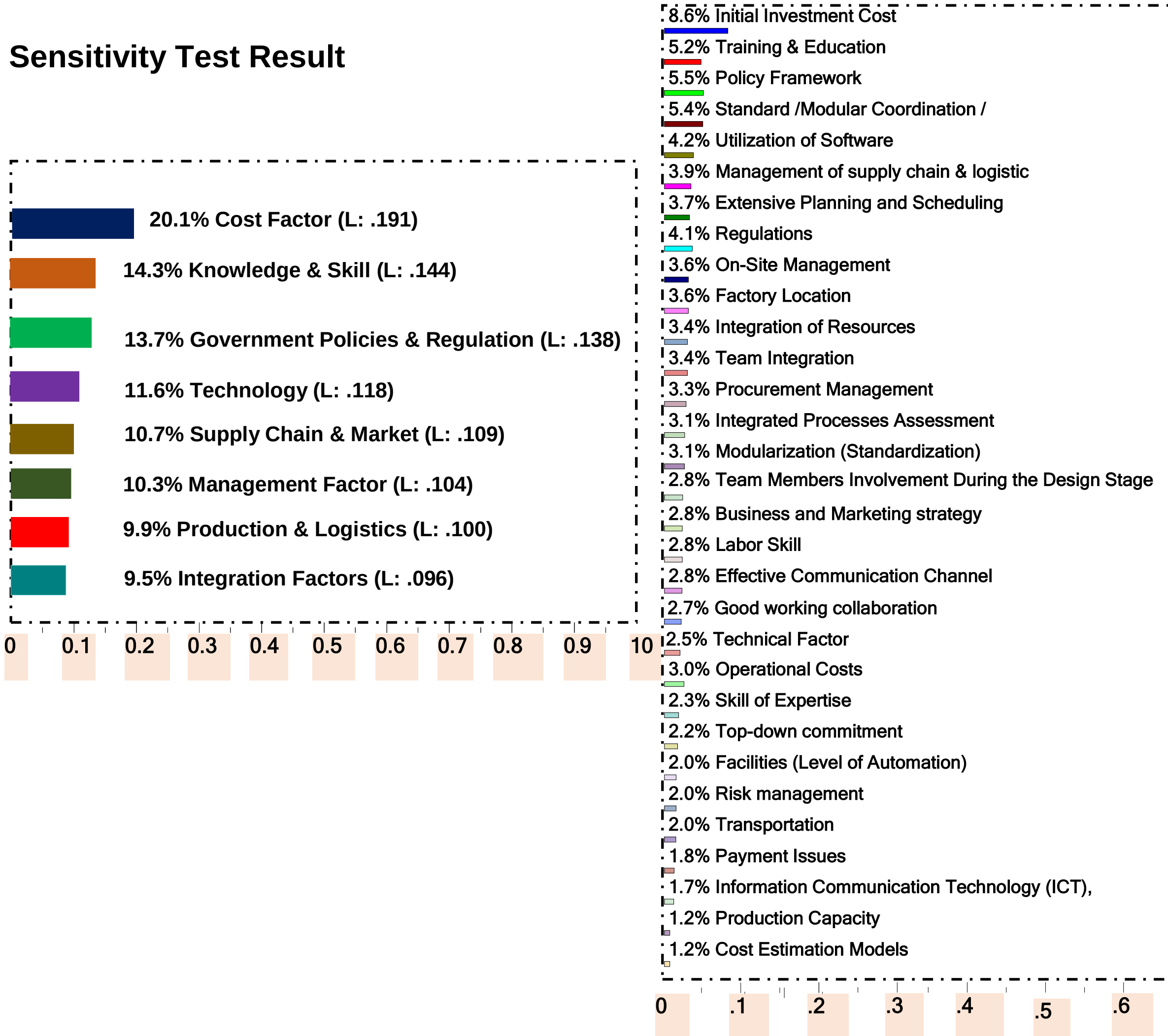

Figure 15: Dynamic Sensitivity Graph for the Sensitivity Test Result

4.8. Analysis of Interview Result for IBS Critical Success Factors

Questionnaires survey and interview were conducted to investigate the CSF the affect the implementation of IBS construction for mass housing provision so that the result will be cross checked against the prioritized CSF. The interview is conducted in person and the 34 respondents' response is presented in table 23 and the summarized as follows as shown in table 21.

The result shows that, the result from the prioritization analysis using the AHP method complies with the response from the identification analysis. Knowledge, cost and government policy and regulation factors found to be critical for the successful implementation of IBS for mass housing construction. The exception from these analyses is the supply chain and market factor are included in top four factors. Whereas the other remaining factors are in perfect compliance with the AHP analysis result, even the ranking interims of respondents' response.

Table 21: Analysis result of CSF Identification that affect IBS Implementation

Responses for the CSF that Affect the Implementation of IBS (From 36 Respondents)	Respondents In %	CSFs
32 participants reply the knowledge and skills about The IBS system affects its implementation	89.0%	Knowledge and skill
28 participants believe that Supply Chain and Market Factor affects its implementation of IBS for mass housing projects	87.5%	Supply Chain and Market Factor
26 responds, Management Factor affect IBS Implementation	72.0%	Management Factor
30 participants reply Cost Factor Affects the IBS implementation	83.0%	Cost Factor
32 respondents, similar to Knowledge factor believe the utilization of technology affects IBS implementation	89.0%	Technology Factor
29 responds, Government Policies & Regulations affects IBS Implementation	80.5%	Government Policies & Regulations
26 participants reply Integration Factor Affects the IBS implementation	72.0%	Integration Factors
27 responds, Production and Logistics Factor affects IBS Implementation	75.0%	Production and Logistic Factor

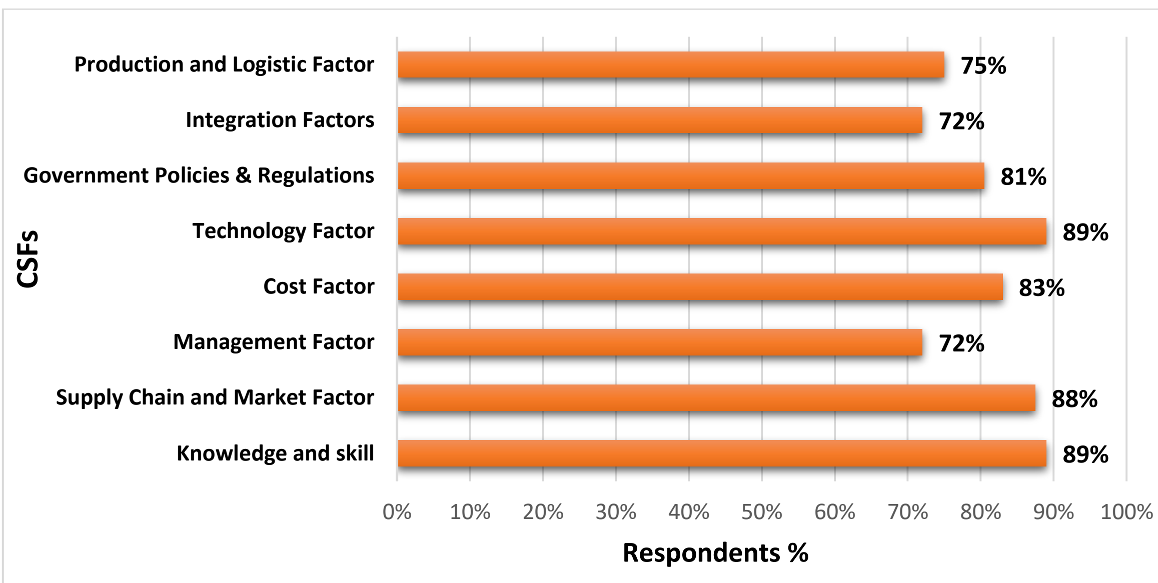

Figure 16: CSF That Affect IBS Implementation

4.9. Potential Advantages of IBS precast concrete system

The survey conducted to identify the potential advantages of IBS precast concrete systems for the provision of housing, the following result is found from the respondents of the questionaries' and also form the interview conducted for key participants. The respondents' data is presented in Table 24 and the result is interpreted and summarized in Table 22 and Figure 17.

Table 22: Analysis Result for potential Advantages of IBS

Responses for the Potential Advantage of IBS (From 36 Respondents)	Respondents In %	Potential Advantages of IBS
34 participants reply, IBS has an advantage to accelerate the construction process.	**94.4%**	**Speed of Construction**
31 participants believe that has an advantage to reduce the material waste during construction	**86.1%**	**Reduction of Waste**
31 responds, IBS can achieve a superior construction quality on the final output	**86.1%**	**Quality**
35 participants reply Cost Efficiency is one of a significant Advantage of IBS in construction of specially for low-cost housing scheme	**97.2%**	**Cost Efficiency**
27 respondents, the implementation of IBS also can have an advantage of achieving Safety during construction process	**75.0%**	**Construction Safety**

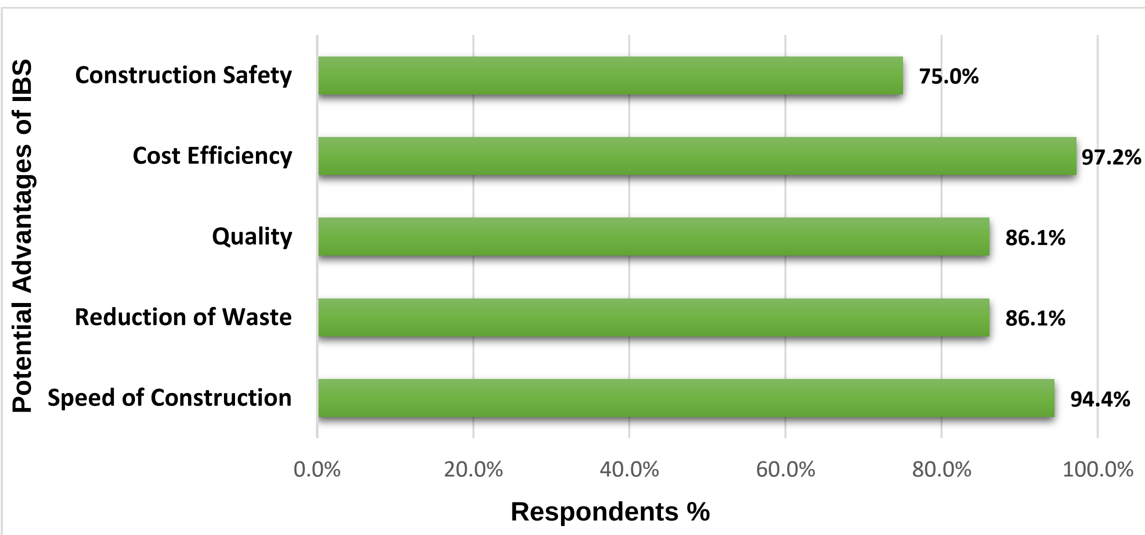

Figure 17: Potential Advantages of IBS Analysis Result

From the analysis result, about 97 % of respondents identify the most important advantage of IBS system is cost efficiency of the system, followed by speed of construction that can be achieved with these systems. Quality and Reduction of waste throughout the construction process is identified as an advantage. The advantage that an IBS system can provide comes last from the five Potential advantages that identified from literature review and included in the research objective.

Table 23: Respondents Data for IBS Critical Success Factors

CSF Affects IBS Implementation	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28	P29	P30	P31	P32	P33	P34	P35	P36	Total √	Total x
CSFi_1	√	√	√	x	√	√	x	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	x	√	√	√	√	√	√	√	x	√	√	32	4
CSFi_2	√	x	x	√	x	√	x	√	√	√	√	x	√	√	√	√	√	√	√	√	x	√	√	√	x	√	√	x	√	√	x	√	√	x	√	√	26	10
CSFi_3	√	√	√	x	√	√	x	√	x	√	x	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	x	x	√	√	√	x	√	√	x	√	28	8
CSFi_4	√	√	√	x	x	√	x	√	√	x	√	√	√	√	√	√	√	√	√	√	√	√	√	√	x	x	√	√	√	√	√	√	√	√	√	√	30	6
CSFi_5	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	x	√	√	√	√	x	√	√	x	x	√	32	4
CSFi_6	√	x	x	√	√	√	√	√	x	x	√	√	√	x	√	√	√	√	√	x	√	√	√	√	√	√	x	√	√	√	√	√	√	√	√	√	29	7
CSFi_7	√	√	√	x	x	√	x	√	√	√	√	√	√	√	√	√	√	√	√	x	√	√	√	√	x	x	√	√	x	√	√	x	√	x	x	√	26	10
CSFi_8	√	√	x	x	√	√	x	√	√	√	√	√	√	√	√	√	√	√	√	x	√	√	√	√	x	√	√	√	x	√	x	√	√	x	√	x	27	9

CSFi_1- Knowledge and skill **CSFi_2 -Supply Chain and Market Factor** **CSFi_3- Management Factor** **CSFi_4- Cost Factor**

CSFi_5- Technology Factor **CSFi_6-Government Policies & Regulations** **CSFi_7- Integration Factors** **CSFi_8 Production and Logistic Factor**

Table 24: Respondents Data for the Identification of Potential of IBS

Expected Advantage of IBS Construction	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28	P29	P30	P31	P32	P33	P34	P35	P36	Total √	Total X
A1	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	x	√	x	√	√	√	√	√	√	√	√	√	34	2
A2	√	√	√	√	√	√	x	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	x	√	√	√	√	x	x	√	√	√	√	x	31	5
A3	√	√	√	√	√	√	x	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	x	√	x	√	√	x	√	x	√	31	5
A4	√	√	√	x	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	35	1
A5	x	x	√	x	√	√	x	√	√	√	x	√	√	√	√	√	√	√	√	√	√	√	√	√	x	√	x	√	√	√	√	x	x	√	√	√	27	9

A1-Speed of Construction **A2-Reduction of Waste** **A3- Quality** **A4-Cost Efficiency** **A5-Construction Safety**

4.10. Cost Analysis

There are several widely used performance indicators for IBS. One of it is construction cost. Cost of construction between conventional construction and IBS construction differs greatly due to the distinguish processes of IBS from traditional way of constructing.

This part of the research analyzes cost comparison between project costs of IBS precast construction method and that of the in-situ construction.

In order to compare the cost of both construction technique, the procedure used is computing the direct cost that the building shown on figure 18 incurred using precast structural elements that includes slab, column, beams and staircase of the building is calculated using PBPPE's cost breakdown templates collected on November 2021, whereas for the in-situ construction method the cost breakdown is done using price rate collected on January 2022 from bill of quantity. The cost does not include the cost of masonry partitions, finishing works, earthwork, or roofing.

The cost estimation used is Bottom-up estimate using unit costs for bill of quantities. The procedure used is, breaking down the construction project into measurable tasks and activities and assigning unit costs to them. Then, these tasks are quantified and each of their quantities are multiplied with their corresponding unit costs. The sum of their products gives the total direct cost. The estimate is a design estimate or conceptual estimate – using a conceptual design of a specific building design shown on Figure 18 for both methods of construction.

The formula used for unit cost calculations is a widely used Formula Based on Labor, Material and Equipment shown below.

Formula (Hendrickson, 2008)

$$y = \sum_{i=1}^{n} y_i = \sum_{i=1}^{n} Q_i (M_i + E_i + W_i L_i)$$

Where

Q_i = work
M_i = unit material cost
E_i = unit equipment rate
L_i = units of labour per unit of Q_i
W_i = wage rate per Li for task 'i

The assumption is that, the location, floor area and number of stories is similar. the cost analysis is done for a ground+ five story building with total floor area 584.5 m^2 located in Addis Ababa. The typical floor of the building is shown on figure 18 below.

For both Construction techniques the total cost, and construction cost per m^2 is generated.

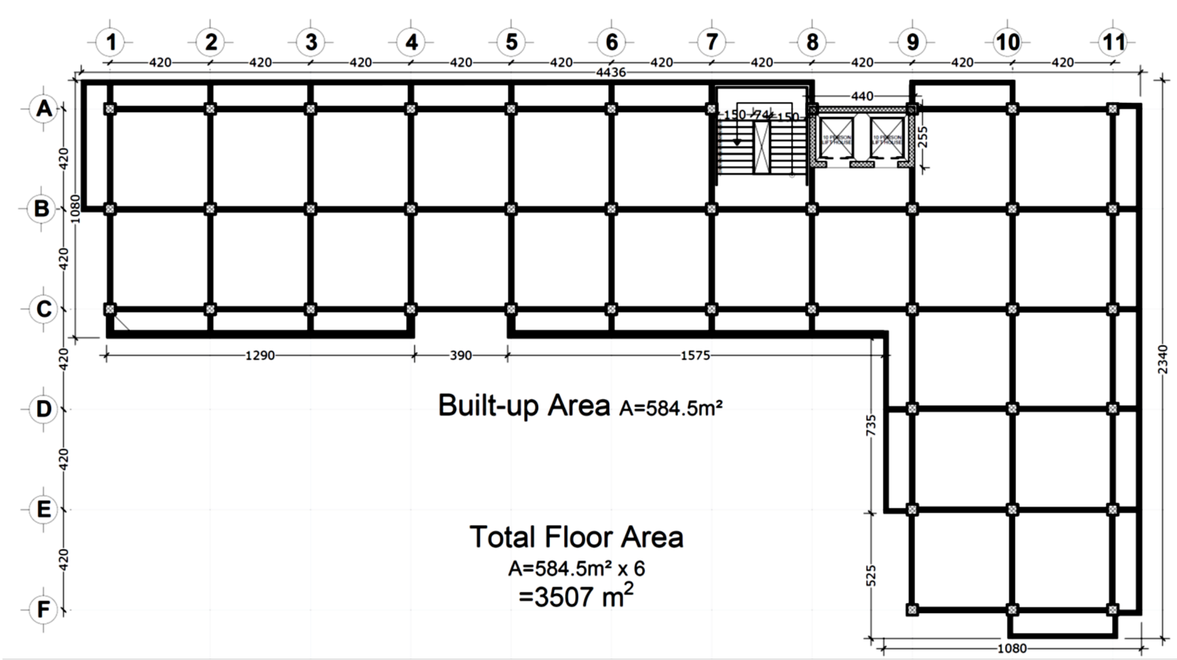

Figure 18: Typical Floor Plan of the Building used for Cost Analysis

The cost Analysis of IBS prefab construction and Traditional (in-situ) construction method is analyzed and presented in the following section.

4.10.1. IBS Precast Concrete Construction Method Cost Analysis

In order to compute construction cost of IBS precast concrete, the above precast building's design showed on figure 18 is analyzed and its material, labor, and equipment costs calculated using PBPPE's design and cost breakdown templates. This supplied the actual direct cost that the building incurred as presented in Appendix D and the summery is shown in table 25 below.

Table 25: Summary of Costs of Precast Construction

Construction of Skeleton in Pre-Fab Elements						
Summary of Costs						
No.	**Description**	**Ground Floor**	**1st- 5Th Floors**	**Qty.**	**Unit Price Br.**	**Total (Birr)**
1	Normal Slab Type S-30-N		151	151	28215.082	4260477.382
2	Cantilever Slab S-30-CL		110	110	11910.108	1310111.88
3	Edge Girder G-30-1		30	30	4901.386	147041.58
4	Edge Girder G-30-2	6		6	5051.676	30310.056
5	Initial Column C-30-1W(L=0.8m)	40		40	9928.31	397132.4
6	Column C-30-1W-2.76m		200	200	9974.762	1994952.4
7	Shear Wall 378*362*15	5	25	30	14565.432	436962.96
8	Staircase Flight	2	10	12	9662.758	115953.096
9	Staircase Landing	1	5	6	20970.558	125823.348
10	Footing Pad F1(120*120*80cm)	27		27	7959.826	214915.302

11	Footing Pad F3(200*200*80cm)	13		13	13564.278	176335.614
Total						**9,210,016.02**
ACTUAL CONSTRUCTION COST is= Total/1.15				**8,008,709.58**		

The construction unit cost of precast construction method is shown in table 26 below.

Table 26: Unit Cost of the IBS Precast Construction Method

	As-Built Area	**Construction Cost, Br**	**Construction Unit Cost, Br/m^2**
Hypothetical Building	3,507	8,008,709.58	**2,283.63**

4.10.2. In-Situ Construction Cost Analysis

The in-situ construction cost shown in Table 27 for the concrete (structure) work of the building, the cost analysis is done using price rate from BOQ based on the same design shown on figure 18. The cost obtained from the analysis is further computed to fine cost per m^2 for in-situ construction method.

Table 27*:* Summary of Costs of In-situ Construction method

Construction of Skeleton using In-situ construction Method				
Summary of Costs				
No.	**Description**	**Ground Floor**	**1St- 5Th Floors**	**Total (Birr)**
1	Ground Floor Slab N	✓		243,124.21
2	Ground Floor Slab CR	✓		56,994.81
3	Suspended Slab N		✓	4,717,765.50
4	Suspended Slab CR		✓	1,153,152.72
5	Main Beams 10.80 m		✓	1,014,687.73
6	Main Beams 44.36 m		✓	1,147,187.46
7	Main Beams 23.40 m	✓	✓	593,783.35
8	Edge Beams	✓	✓	523,317.24
9	Footing Column	✓		567,438.18
10	Elevation Column	✓	✓	2,887,231.20
11	Shear Wall	✓	✓	878,621.04
12	Stair case Flight & landing	✓	✓	418,554.18
13	Footing Pad(120mx120m)	✓		322,380.32
14	Footing Pad(200mx200m)	✓		445,262.77
Total				**14,969,500.71**
Actual Construction Cost is= Total/1.15				**13,016,957.14**

The construction unit cost of precast construction method is shown in table 26 below.

Table 28: Summary of Costs of Precast Construction

	As-Built Area	Construction Cost, Br	Construction Unit Cost, Br/m^2
Hypothetical Building	3,507	13,016,957.14	**3,711.70**

4.10.3. Cost Comparison Analysis

From the cost analysis the building skeleton unit cost of the prefab method is 2283.63 ETB whereas the in-situ unit cost for the similar building found to be 3711.70 ETB. These results clearly show that precast construction costs significantly less than the in-situ construction method. The figures in Table 26 and 28 are not inclusive of the indirect cost components that would incur due to the abundant difference in the speed of construction between the two construction methods. According to (Chane, 2017), to compare the construction cost of both method number of floors and building typology have a significant influence to obtain the cost advantage of IBS precast system. The research further indicates that the incremental nature of the inputs in the in-situ method of construction would always have a volume at which it ceases to be an economic choice when compared to a systematic precast method where initial investments are made for the affordability, speed, quality and ease of subsequent construction.

These results show that precast construction cost is less than the in-situ construction method. The figures in table 26 and table 28 are not inclusive of the indirect cost components that would ensue due to the difference in the speed of construction between the two construction methods.

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATION

5.1. Introduction

This chapter concludes the research work by addressing the research objective and showing how the research questions have been answered. It presents the research findings, conclusions and recommendations.

The two primary research questions posed at the beginning of the research process were, "What are the potential benefits of utilizing IBS precast concrete technology for the house construction sector in Addis Ababa?" and “What are the critical success factors for the successful implementation of the IBS precast concrete system for mass housing projects in Addis Ababa?”.

The research, based on the first research question, have identified and prioritize the critical success factors for the implementation of IBS and rank the potential advantages of IBS in the construction of mass housing projects. the research uses a combination of questionnaire and interview survey data for primary data source and, literature source for secondary data source. First, the research revealed 8 CSF on first level and further 31 alternative factors categorized under the eight CSF and have prioritized the identified CSF using both qualitative and quantitative data collected from systematically selected stakeholders in the sector. the analysis is done using the AHP analysis method using Expert Choice Software,

Second, the research identify the potential advantages of adopting IBS system. The research presents the most prominent advantages identified through an in-depth study of various resources in the IBS research and analyze the participant’s response to rank this potential advantages.

The analysis also further presents the cost analysis of this system compared to the conventional construction method to reinforce the outcome of the research findings.

5.2. Conclusion

Introduction of modern technologies as well as building system innovation has a significant potential to contribute towards many aspects of construction industry including improving constructions efficiency and sustainability. IBS has been proven in terms of its potential advantages such as minimizing construction wastage, reducing project cost, improving quality and reducing construction duration. To harness these potentials, identifying and analyzing those critical success factors for its implementation is very important in advance of selecting the system especially for large scale public projects like mass housing projects.

The implementation of this system is still far reaching as it faces a lot of barriers in the project life cycle. This research paper aim, identifying the critical factors and presenting its potential advantages particularly to facilitate the provision of mass housing in Addis Ababa, where housing shortage is one of the most critical issues for the city residents, where the city administration is challenged to deliver through the conventional construction method.

The research undergoes a systematic review of studies to better understand IBS and underpin the factors influencing IBS success. The findings of the research present not only the prioritized critical success factors based of their influence for its success but also rank the prominent potential advantage of the system using both qualitative and quantitative survey data collected from stakeholders.

In conclusion, first the research present ranked five potential advantages that can be harnessed from adopting IBS for mass housing projects. From the ranked potential advantages of IBS in housing construction sector, cost efficiency of the system is found to be ranked first. This advantage of IBS also justifies the utilization of the system, especially for low-cost housing scheme in which project cost is a critical factor to achieve its objective. Second advantage of IBS system found to be influential, is its advantage to realize housing projects within a scheduled time or even shorten the construction period of housing projects which is one of the challenges facing housing projects across the city.

This challenge does not only affect the house seekers to wait for an extended period of time to become house owner and deny the economic benefit from owning their house but also it affects housing affordability as an extended schedule affect the construction cost due to inflation that rise the transfer cost of the housing units.

Ranked third, reduction of construction waste is also the other advantage of IBS, since it reduces the construction process because of most of the units are manufactured in off-site where the production process is optimized. This advantage of IBS also indirectly affects the construction cost of housing units. The other potential advantage ranked forth is the construction quality that can be realized using IBS. Due to semi-finished units which is used and assembled on-site both aesthetic and structural quality can be attained easily and with less cost than the conventional construction method. And finally, construction safety is the other advantage ranked fifth that can be obtained from IBS utilization. Those safety issues rose from using scaffolding and on-site intensive activities during the project life cycle; IBS utilization has an advantage of reducing safety issues with less labor-intensive activity and through more mechanized assembly process.

In terms of critical success factors, the prioritized CSFs for implementing the IBS construction approach are ranked according to their relative importance. The cost factor is raked first, since IBS system adaptation necessitates mass production of building units, which demands high initial investment capital designated for machineries, technology, transportation, and the wages of skilled workers for the installation process, as well as financial problems emanating from building materials and land costs, have a significant impact on investors in the sector.

The second most influential factor is knowledge. Knowledge factors, such as the availability of well-educated human capital and expertise in IBS, play a significant role in the success of IBS initiatives. Successful IBS implementation necessitates specialized knowledge and expertise in processes, design, and manufacturing, which are in short supply in the local labor market. The availability of skilled construction specialists with the necessary competence to guide the way is critical for the success of an IBS project in terms of performance.

Government policies and regulations are placed third in terms of influencing or affecting IBS implementation, particularly modular coordination, which advocates for the formulation of a regulatory framework to apply uniform or universal measurement and component assembly techniques. The government's engagement in creating mandatory regulations or building codes is crucial in ensuring that all stakeholders involved in IBS implementation are on the same page. The introduction of formal IBS building regulations or standards for contract agreements or contract administration in terms of tendering, design, construction, and payment model is crucial for IBS implementation for mass housing projects.

Communication has a significant impact on the success of a construction project. Ranked fourth, efficiency of communication between stakeholders can facilitate the construction process commencing with design, manufacturing, and onsite installation are highly associated to the technology utilization factor. Failing to implement an effective communication channel can contribute to problems such as double handling, time delays, and data handling, all of which will have a detrimental impact on the cost of operation, quality, and total project duration. In the era of BIM, the use of appropriate software and information technology that affect the communication process.

In the aspect of Supply chain and market factor ranked fifth, the IBS requirement for a high level of coordination and integration of supply chains from design, manufacturing, and construction stages affects its success.

The sixth-placed management factors are also the core of the whole supply chain system in the industrialized building system. According to the finding, extensive planning and scheduling, as well as on-site management are the most important influential factors in the implementation of IBS. Effective planning and scheduling would ensure that all stakeholders understand their responsibilities which improve project performance, coordination, scope control, and ensure a smooth project sequence. Extensive planning and scheduling of tasks in advance is crucial. Especially contractors stressed, the standardized procedures and production lines for producing components depends no flexibility for adapting and responding to changes, which requires a through on-site management

The Production and Logistics ranked seventh. Especially factory location with respect to construction sites is ranked high in the factor priority list. Strategic location of production facility is considered as one of the factors for the successful implementation of IBS in relation to the project location. It has a significant implication to the cost of constriction. Transportation issues as a result of the of factory location with respect to the construction site is one of the challenges in managing IBS construction.

The last factor ranked eighth is an integration factor, process integration involving all subsystems, components, manufacturing and construction processes, and which all requires efficient management. IBS's success is influenced by the level of integration, both material and human resources. a strong working collaboration, good communication channels, team members' engagement throughout the design stage, close ties with suppliers, and comprehensive planning and scheduling is crucial

Finlay, to harness the ranked potential advantages of IBS for mass housing construction in Addis Ababa, a comprehensive effort is required from stakeholder in the sector to address the prioritized success factors for a successful Implementation of IBS for mass housing construction.

5.3. Recommendations

Despite its multifaceted ramifications, access to affordable and decent housing has long been a challenge in Addis Ababa. With the goal of meeting the overwhelming demand for housing, the adoption of IBS for mass housing is a prominent construction approach. In recognition to potential advantages of IBS, the housing construction industry needs an innovative construction approach to expedite the provision of dwellings in Addis Ababa.

With an objective to successfully and adequately deliver mass housing, the research present potential advantages and those factors which influence the IBS implementation so that stakeholder awareness regarding the potentials utilizing appropriate IBS could be raised and achieving stakeholders' objectives.

According to the finding, Government policies have been prominent in promoting new construction techniques in the construction industry, simply because the government is the major clients in the construction industry, especially the housing development sector in Addis Ababa

Finally, the research recommend the following recommendations based of the research findings that positively contribute towards IBS application for mass housing project pertaining to IBS implementation, such as

- Establishing standards for IBS should be adopted so that the supply chain should comprise of modular component-based products that can be produce and interchangeable between any project thus promote mass customization at the customers' end.
- The introduction of Modular Coordination in which coordination of dimensions and space where buildings and components are dimensioned and positioned in a basic unit or module.
- In order to ensure optimum and continuous performance, periodical financing is recommended as an alternative to support the private sector involving in the sector, especially to offset the burden of initial investment cost incurred in the procurement of machinery used in component manufacturing
- Inclusion of IBS construction technique in national education curriculum so that the IBS construction method could be an integral knowledge of both technical schools and higher institutions.
- Benchmarking and partnership with foreign expert to acquire knowledge through technology transfer to build up own capacity in IBS technologies should be prioritized to contribute to national technological self-reliance.
- Selection of strategic location for IBS industries in relation to mass housing construction site should be considered highly.
- Encouraging research and development efforts in relation to IBS technology adoption and advanced software utilization like BIM and CAD should be prioritized broadly.
- Accordingly, inclusion of IBS construction method in housing policy and strategy formulation should be recognized

5.4. Recommendation for Further Studies

While answering the research questions, I acknowledge that this work is one small part in a much wider puzzle in the provision of mass housing. Rather, to further understand IBS system the areas requiring further research. In the future I recommend further research on strategic mechanisms regarding how to unlock these critical success factors.

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Appendix 1: Interview Questions

Q1: In your opinion, *what are the potential critical success factors that encourages the use of Industrial building system (IBS) for mass house construction*?

Q2: *From your experience in the construction sector what are the potentials/advantages in using IBS for mass house projects?*

Q3: *In your opinion, do you think IBS can play any significant improvement in the effort of the construction of mass housing in the city?*______________________ *how?* -----
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Q4: *From your experience, what should be done to increase the current utilization of IBS for housing development?*____

____

___________________________. *Who do you think are the main stakeholders for to facilitate the technology?* --
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Appendix 2

Appendix 2: Questionnaires Form

Code 2.1. For professionals in the construction sector

1. What is your professional Background (Check)?

ARCHITECT ☐ **CON. ENGINEER** ☐ **CONSTRUCTION MANAGER** ☐

2. Period of involvement in the construction industry ________________Years.

3. Based on your past experience with IBS construction, what were the expected benefits of using IBS for mass housing development? (select all that apply)

Speed of construction ☐ **Cost-effectiveness** ☐

Reduction in waste ☐ **Construction Safety** ☐

Quality ☐

If any Other______________________________________

4. Based on your past experience with IBS construction, which of the following factors do you think affect the implementation of IBS in Mass housing projects? (select all that apply)

KNOWLEDGE AND SKILL ☐ **TECHNOLOGY** ☐

SUPPLY CHAIN & MARKET FACTOR ☐ **GOVERNMENT POLICIES & REGULATION** ☐

MANAGEMENT FACTORS ☐ **INTEGRATION FACTOR** ☐

PRODUCTION & LOGISTICS ☐ **COST FACTOR** ☐

If any Other____

5. Pleas rate the following Critical success factors using the following rating scaling method:

Intensity of Importance	Definition	Explanation	Reciprocal
1	Equal importance	Two elements contribute equally to the objective	**1**
3	Moderate Importance	Experience and judgement moderately favour one element over the other	**1/3**
5	Strong Importance	Experience and judgement Strongly favour one element over the other	**1/5**
7	Very strong Importance	One element is favoured very strongly over another, its dominance is demonstrated in practice	**1/7**
9	Extreme Importance	The evidence favouring one element over another is of the highest possible order of affirmation	**1/9**
2,4,6,8	Intermediate values between the two adjacent judgments	When compromise is needed	**1/2,1/4,1/6,1/8**
Reciprocals	If activity *i* has one of the above numbers assigned to It when compared with activity *j,* then *j* has the reciprocal value when compared with *i*		

Source: **(Saaty R. , 1987)**

FACTORS	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	FACTORS
Knowledge And Skill																		**Supply Chain & Market Factor**
Knowledge And Skill																		**Management Factors**
Knowledge And Skill																		**Cost Factor**
Knowledge And Skill																		**Technology**
Knowledge And Skill																		**Government Policies & Regulation**
Knowledge And Skill																		**Integration Factor**
Knowledge And Skill																		**Production & Logistics**
Supply Chain & Market Factor																		**Management Factors**
Supply Chain & Market Factor																		**Cost Factor**
Supply Chain & Market Factor																		**Technology**
Supply Chain & Market Factor																		**Government Policies & Regulation**
Supply Chain & Market Factor																		**Integration Factor**
Supply Chain & Market Factor																		**Production & Logistics**
Management Factors																		**Cost Factor**
Management Factors																		**Technology**
Management Factors																		**Government Policies & Regulation**
Management Factors																		**Integration Factor**
Management Factors																		**Production & Logistics**
Cost Factor																		**Technology**
Cost Factor																		**Government Policies & Regulation**
Cost Factor																		**Integration Factor**
Cost Factor																		**Production &**

																		Logistics
Technology																		**Government Policies & Regulation**
Technology																		**Integration Factor**
Technology																		**Production & Logistics**
Government Policies & Regulation																		**Integration Factor**
Government Policies & Regulation																		**Production & Logistics**
Integration Factor																		**Production & Logistics**

6. Pleas Rate the Following Critical Success Factor using the above Rating Scale

INTEGRATION FACTOR								**[CSF (i7)]**										
CSFs	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	CSFs
Integration Of Resources																		Team Integration
Integration Of Resources																		Integrated Processes Assessment
Team Integration																		Integrated Processes Assessment
TECHNOLOGY FACTOR							**[CSF (i5)]**											
Utilization Of Software																		Information Communication Technology (ICT),
SUPPLY CHAIN & MARKET FACTOR							**[CSF (i2)]**											
Management Factors																		Procurement Management
Management of supply chain and logistic																		Business and Marketing strategy
Management of supply chain and logistic																		Payment Issues
Procurement Management																		Business and Marketing strategy
Procurement Management																		Payment Issues
Business and Marketing strategy																		Payment Issues

Code 2.2: For Institutions and Companies

1. What is **the primary service that your company provides**? (Check)

Consultant ☐ **Contractor** ☐ **Developer** ☐

2. Period of involvement in the construction industry _________________Years.

3. Based on your past experience with IBS construction, what were the expected benefits of using IBS for mass housing development? (select all that apply)

Speed of construction ☐ **Cost-effectiveness** ☐

Reduction in waste ☐ **Construction Safety** ☐

Quality ☐

If any Other____

4. Based on your past experience with IBS construction, which of the following factors do you think affect the implementation of IBS in Mass housing projects? (select all that apply)

KNOWLEDGE AND SKILL ☐ **TECHNOLOGY** ☐

SUPPLY CHAIN & MARKET FACTOR ☐ **GOVERNMENT POLICIES & REGULATION** ☐

MANAGEMENT FACTORS ☐ **INTEGRATION FACTOR** ☐

PRODUCTION & LOGISTICS ☐ **COST FACTOR** ☐

If any Other____

5. Pleas rate the following Critical success factors using the following rating scaling method:

Intensity of Importance	Definition	Explanation	Reciprocal
1	Equal importance	Two elements contribute equally to the objective	**1**
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7	Very strong Importance	One element is favoured very strongly over another, its dominance is demonstrated in practice	**1/7**
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2,4,6,8	Intermediate values between the two adjacent judgments	When compromise is needed	**1/2,1/4,1/6,1/8**
Reciprocals	If activity *i* has one of the above numbers assigned to It when compared with activity *j*, then *j* has the reciprocal value when compared with *i*		

Source: **(Saaty R. , 1987)**

FACTORS	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	FACTORS
Knowledge And Skill																		**Supply Chain & Market Factor**
Knowledge And Skill																		**Management Factors**
Knowledge And Skill																		**Cost Factor**
Knowledge And Skill																		**Technology**
Knowledge And Skill																		**Government Policies & Regulation**
Knowledge And Skill																		**Integration Factor**
Knowledge And Skill																		**Production & Logistics**
Supply Chain & Market Factor																		**Management Factors**
Supply Chain & Market Factor																		**Cost Factor**
Supply Chain & Market Factor																		**Technology**
Supply Chain & Market Factor																		**Government Policies & Regulation**
Supply Chain & Market Factor																		**Integration Factor**
Supply Chain & Market Factor																		**Production & Logistics**
Management Factors																		**Cost Factor**
Management Factors																		**Technology**
Management Factors																		**Government Policies & Regulation**
Management Factors																		**Integration Factor**
Management Factors																		**Production & Logistics**
Cost Factor																		**Technology**
Cost Factor																		**Government Policies & Regulation**
Cost Factor																		**Integration Factor**
Cost Factor																		**Production & Logistics**
Technology																		**Government Policies & Regulation**
Technology																		**Integration Factor**
Technology																		**Production & Logistics**
Government Policies & Regulation																		**Integration Factor**

Government Policies & Regulation																		**Production & Logistics**
Integration Factor																		**Production & Logistics**

6. Pleas Rate the Following Critical Success Factor using the above Rating Scale

INTEGRATION FACTOR	**[CSF (i7)]**																	
CSFs	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	CSFs
Integration Of Resources																		Team Integration
Integration Of Resources																		Integrated Processes Assessment
Team Integration																		Integrated Processes Assessment
TECHNOLOGY FACTOR	**[CSF (i5)]**																	
Utilization Of Software																		Information Communication Technology (ICT),
SUPPLY CHAIN & MARKET FACTOR	**[CSF (i2)]**																	
Management Factors																		Procurement Management
Management of supply chain and logistic																		Business and Marketing strategy
Management of supply chain and logistic																		Payment Issues
Procurement Management																		Business and Marketing strategy
Procurement Management																		Payment Issues
Business and Marketing strategy																		Payment Issues
MANAGEMENT FACTORS	**[CSF (i3)]**																	
Good working collaboration																		Effective Communication Channel
Good working collaboration																		Team Members Involvement During the Design Stage
Good working collaboration																		Risk management
Good working collaboration																		Extensive Planning and Scheduling
Good working																		Top-down

collaboration																		commitment
Good working collaboration																		On-Site Management
Good working collaboration																		Technical Factor
Effective Communication Channel																		Team Members Involvement During the Design Stage
Effective Communication Channel																		Risk management
Effective Communication Channel																		Extensive Planning and Scheduling
Effective Communication Channel																		Top-down commitment
Effective Communication Channel																		On-Site Management
Effective Communication Channel																		Technical Factor
Team Members Involvement During the Design Stage																		Risk management
Team Members Involvement During the Design Stage																		Extensive Planning and Scheduling
Team Members Involvement During the Design Stage																		Top-down commitment
Team Members Involvement During the Design Stage																		On-Site Management
Team Members Involvement During the Design Stage																		Technical Factor
Risk management																		Extensive Planning and Scheduling
Risk management																		Top-down commitment
Risk management																		On-Site Management
Risk management																		Technical Factor
Extensive Planning and Scheduling																		Top-down commitment
Extensive Planning and Scheduling																		On-Site Management
Extensive Planning and Scheduling																		Technical Factor
Top-down commitment																		On-Site Management
Top-down commitment																		Technical Factor

On-Site Management																	Technical Factor
KNOWLEDGE AND SKILL FACTORS									**[CSF (i1)]**								
Training & Education																	Labour skill
Training & Education																	Skill of Expertise
Labour skill																	Skill of Expertise
COST FACTORS									**[CSF (i4)]**								
Initial investment cost																	Operational costs
Initial investment cost																	Cost Estimation Models
Operational costs																	Cost Estimation Models
GOVERNMENT POLICIES & REGULATION										**[CSF (i6)]**							
Policy Framework																	Regulations
Policy Framework																	Standard /Modular Coordination /
Regulations																	Standard /Modular Coordination /

Code2.3: For Manufacturers and Importers

1. What is your Service area (Check)?

Manufacturer ☐ **Importer** ☐

2. Period of involvement in the construction industry ________________Years.

3. Based on your past experience with IBS construction, what were the expected benefits of using IBS for mass housing development? (select all that apply)

Speed of construction ☐ **Cost-effectiveness** ☐

Reduction in waste ☐ **Construction Safety** ☐

Quality ☐

If any Other______________________________________

4. Based on your past experience with IBS construction, which of the following factors do you think affect the implementation of IBS in Mass housing projects? (select all that apply)

KNOWLEDGE AND SKILL ☐ **TECHNOLOGY** ☐

SUPPLY CHAIN & MARKET FACTOR ☐ **GOVERNMENT POLICIES & REGULATION** ☐

MANAGEMENT FACTORS ☐ **INTEGRATION FACTOR** ☐

PRODUCTION & LOGISTICS ☐ **COST FACTOR** ☐

If any Other____

5. Pleas rate the following Critical success factors using the following rating scaling method:

Intensity of Importance	Definition	Explanation	Reciprocal
1	Equal importance	Two elements contribute equally to the objective	**1**
3	Moderate Importance	Experience and judgement moderately favour one element over the other	**1/3**
5	Strong Importance	Experience and judgement Strongly favour one element over the other	**1/5**
7	Very strong Importance	One element is favoured very strongly over another, its dominance is demonstrated in practice	**1/7**
9	Extreme Importance	The evidence favouring one element over another is of the highest possible order of affirmation	**1/9**
2,4,6,8	Intermediate values between the two adjacent judgments	When compromise is needed	**1/2,1/4,1/6,1/8**
Reciprocals	If activity *i* has one of the above numbers assigned to It when compared with activity *j*, then *j* has the reciprocal value when compared with *i*		

Source: **(Saaty R. , 1987)**

FACTORS	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	FACTORS
Knowledge And Skill																		**Supply Chain & Market Factor**
Knowledge And Skill																		**Management Factors**
Knowledge And Skill																		**Cost Factor**
Knowledge And Skill																		**Technology**
Knowledge And Skill																		**Government Policies & Regulation**
Knowledge And Skill																		**Integration Factor**
Knowledge And Skill																		**Production & Logistics**
Supply Chain & Market Factor																		**Management Factors**
Supply Chain & Market Factor																		**Cost Factor**
Supply Chain & Market Factor																		**Technology**
Supply Chain & Market Factor																		**Government Policies & Regulation**
Supply Chain & Market Factor																		**Integration Factor**
Supply Chain & Market Factor																		**Production & Logistics**
Management Factors																		**Cost Factor**
Management Factors																		**Technology**
Management Factors																		**Government Policies & Regulation**
Management Factors																		**Integration Factor**
Management Factors																		**Production & Logistics**
Cost Factor																		**Technology**
Cost Factor																		**Government Policies & Regulation**
Cost Factor																		**Integration Factor**
Cost Factor																		**Production & Logistics**
Technology																		**Government Policies & Regulation**
Technology																		**Integration Factor**

Technology																		**Production & Logistics**
Government Policies & Regulation																		**Integration Factor**
Government Policies & Regulation																		**Production & Logistics**
Integration Factor																		**Production & Logistics**

6. Pleas Rate the Following Critical Success Factor using the above Rating Scale

INTEGRATION FACTOR																		**[CSF (i7)]**
CSFs	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	CSFs
Integration Of Resources																		Team Integration
Integration Of Resources																		Integrated Processes Assessment
Team Integration																		Integrated Processes Assessment
TECHNOLOGY FACTOR																		**[CSF (i5)]**
Utilization Of Software																		Information Communication Technology (ICT),
SUPPLY CHAIN & MARKET FACTOR																		**[CSF (i2)]**
Management Factors																		Procurement Management
Management of supply chain and logistic																		Business and Marketing strategy
Management of supply chain and logistic																		Payment Issues
Procurement Management																		Business and Marketing strategy
Procurement Management																		Payment Issues
Business and Marketing strategy																		Payment Issues
MANAGEMENT FACTORS																		**[CSF (i3)]**
Good working collaboration																		Effective Communication Channel
Good working collaboration																		Team Members Involvement During the Design Stage
Good working collaboration																		Risk management
Good working collaboration																		Extensive Planning and Scheduling
Good working collaboration																		Top-down commitment
Good working collaboration																		On-Site Management
Good working collaboration																		Technical Factor
Effective Communication Channel																		Team Members Involvement During the Design Stage
Effective Communication																		Risk management

Channel																		
Effective Communication Channel																		Extensive Planning and Scheduling
Effective Communication Channel																		Top-down commitment
Effective Communication Channel																		On-Site Management
Effective Communication Channel																		Technical Factor
Team Members Involvement During the Design Stage																		Risk management
Team Members Involvement During the Design Stage																		Extensive Planning and Scheduling
Team Members Involvement During the Design Stage																		Top-down commitment
Team Members Involvement During the Design Stage																		On-Site Management
Team Members Involvement During the Design Stage																		Technical Factor
Risk management																		Extensive Planning and Scheduling
Risk management																		Top-down commitment
Risk management																		On-Site Management
Risk management																		Technical Factor
Extensive Planning and Scheduling																		Top-down commitment
Extensive Planning and Scheduling																		On-Site Management
Extensive Planning and Scheduling																		Technical Factor
Top-down commitment																		On-Site Management
Top-down commitment																		Technical Factor
On-Site Management																		Technical Factor
KNOWLEDGE AND SKILL FACTORS																		**[CSF (i1)]**
Training & Education																		Labour skill
Training & Education																		Skill of Expertise
Labour skill																		Skill of Expertise
COST FACTORS																		**[CSF (i4)]**
Initial investment cost																		Operational costs
Initial investment cost																		Cost Estimation Models
Operational costs																		Cost Estimation Models
PRODUCTION & LOGISTICS FACTORS																		**[CSF (i8)]**
Facilities (Level of Automation)																		Transportation
Facilities (Level of Automation)																		Modularization(Standardization)
Facilities (Level of Automation)																		Factory Location
Facilities (Level of Automation)																		Production Capacity
Transportation																		Modularization(Standardization)
Transportation																		Factory Location
Transportation																		Production Capacity

Modularization(Standardization)																		Factory Location
Modularization(Standardization)																		Production Capacity
Factory Location																		Production Capacity
GOVERNMENT POLICIES & REGULATION [CSF (i6)]																		
Policy Framework																		Regulations
Policy Framework																		Standard /Modular Coordination /
Regulations																		Standard /Modular Coordination /

Appendix 3: Cost Analysis

Cost breakdown for Pre-Fabricated Elements using IBS construction method

Cost Breakdown for Production and Erection			
Pre-Fabricated Building Elements			
Project:		**Hypothetical Building**	
Work Item:	**Cantilever Slab S-30-CL(CR)**		
	Total Production Cost		4,745.04
	Total Erection:		3885.47
Total Production and Erection:		8,630.51	
Add 20% Overhead: 1.20			10,356.61
Add 15% Profit			11,910.11
Grand Total			**11,910.11**
Work Item:	**Edge Girder G-30-2**		
	Total Production Cost		2,278.40
	Total Erection:		1382.23
Total Production and Erection:		3,660.63	
Add 20% Overhead: 1.20			4,392.76
Add 15% Profit			5,051.68
Grand Total			**5,051.68**
Work Item:	**Edge Girder G-30-1**		
	Total Production Cost		2,139.25
	Total Erection:		1412.48
Total Production and Erection:		3,551.73	
Add 20% Overhead: 1.20			4,262.07
Add 15% Profit			4,901.39
Grand Total			**4,901.39**
Work Item:	**Column C-30-1W, 2.9m**		
	Total Production Cost		3,876.90
	Total Erection:		3351.18
Total Production and Erection:		7,228.08	
Add 20% Overhead: 1.20			8,673.70
Add 15% Profit			9,974.76
Grand Total			**9,974.76**
Work Item:	**Normal Slab without Ceiling, S-30-N**		
	Total Production Cost		12,900.60
	Total Erection:		7,545.11
Total Production and Erection:		20,445.71	
Add 20% Overhead: 1.20			24,534.85
Add 15% Profit			28,215.08
Grand Total			**28,215.08**
Work Item:	**Normal S/W SWN (378X362X15)**		
	Total Production Cost		8,773.05
	Total Erection:		1781.60

Total Production and Erection:		10,554.65	
Add 20% Overhead: 1.20			12,665.59
Add 15% Profit			14,565.43
Grand Total			**14,565.43**
Project:		Islamic Affairs Building	
Work Item:	**Staircase Flight**		
	Total Production Cost		4,487.58
	Total Erection:		2514.42
Total Production and Erection:		7,002	
Add 20% Overhead: 1.20			8,402.4
Add 15% Profit			9,662.76
Grand Total			**9,662.76**
Work Item:	**Staircase Landing**		
	Total Production Cost		11,944.33
	Total Erection:		3251.72
Total Production and Erection:		15,196.05	
Add 20% Overhead: 1.20			18,235.26
Add 15% Profit			20,970.56
Grand Total			**20,970.56**
Work Item:	**Footing F1 (120X120X80cm)**		
	Total Production Cost		3,914.67
	Total Erection:		1853.32
Total Production and Erection:		5,767.99	
Add 20% Overhead: 1.20			6,921.59
Add 15% Profit			7,959.83
Grand Total			**7,959.83**
Work Item:	**Footing F3 (200X200X80cm)**		
	Total Production Cost		5,546.47
	Total Erection:		4,282.71
Total Production and Erection:		9,829.18	
Add 20% Overhead: 1.20			11,795.02
Add 15% Profit			13,564.28
Grand Total			**13,564.28**

Cost breakdown for building Elements using Traditional(in-situ) construction method

No.	Description	Unit	Quantity/ Element	Number Of Elements	Total Quantity	Rate (Birr)	Total Cost (Birr)
1	Ground Floor Slab N						
	1. Concrete	m^3	1.60	26.00	41.60	3,251.01	**135,242.02**
	2. Rebar	kg	65.55	26.00	1,704.30	63.30	**107,882.19**
2	Ground Floor Slab CR						
	1. Concrete	m^3	0.38	24.00	9.12	3,251.01	**29,649.21**
	2. Rebar	kg	18.00	24.00	432.00	63.30	**27,345.60**
3	Suspended Slab N						
	1. Concrete	m^3	2.40	125.00	300.00	3,251.01	**975,303.00**
	2. Formwork	m^2	16.00	125.00	2,000.00	648.75	**1,297,500.00**
	3. Rebar	kg	309.00	125.00	38,625.00	63.30	**2,444,962.50**
4	Suspended Slab CR						
	1. Concrete	m^3	0.60	120.00	72.00	3,251.01	**234,072.72**
	2. Formwork	m^2	4.00	120.00	480.00	648.75	**311,400.00**
	3. Rebar	kg	80.00	120.00	9,600.00	63.30	**607,680.00**
5	Main Beams 10.80 m				-		**-**
	1. Concrete	m^3	0.65	66.00	42.90	3,251.01	**139,468.33**
	2. Formwork	m^2	6.00	66.00	396.00	648.75	**256,905.00**
	3. Rebar	kg	148.00	66.00	9,768.00	63.30	**618,314.40**
6	Main Beams 44.36 m						
	1. Concrete	m^3	2.66	18.00	47.88	3,251.01	**155,658.36**
	2. Formwork	m^2	25.00	18.00	450.00	648.75	**291,937.50**
	3. Rebar	kg	614.00	18.00	11,052.00	63.30	**699,591.60**
7	Main Beams 23.40 m						
	1. Concrete	m^3	1.40	18.00	25.20	3,251.01	**81,925.45**
	2. Formwork	m^2	13.00	18.00	234.00	648.75	**151,807.50**
	3. Rebar	kg	316.00	18.00	5,688.00	63.30	**360,050.40**
8	Edge Beams						
	1. Concrete	m^3	0.20	120.00	24.00	3,251.01	**78,024.24**
	2. Formwork	m^2	2.50	120.00	300.00	648.75	**194,625.00**
	3. Rebar	kg	33.00	120.00	3,960.00	63.30	**250,668.00**
9	Footing Column						
	1. Concrete	m^3	0.45	40.00	18.00	3,251.01	**58,518.18**
	2. Formwork	m^2	4.00	40.00	160.00	648.75	**103,800.00**
	3. Rebar	kg	160.00	40.00	6,400.00	63.30	**405,120.00**

10	Elevation Column						
	1. Concrete	m^3	0.60	200.00	120.00	3,251.01	**390,121.20**
	2. Formwork	m^2	5.00	200.00	1,000.00	648.75	**648,750.00**
	3. Rebar	kg	146.00	200.00	29,200.00	63.30	**1,848,360.00**
11	Shear Wall						
	1. Concrete	m^3	9.00	6.00	54.00	3,251.01	**175,554.54**
	2. Formwork	m^2	85.00	6.00	510.00	648.75	**330,862.50**
	3. Rebar	kg	980.00	6.00	5,880.00	63.30	**372,204.00**
12	Stair Case Flight & Landing						
	1. Concrete	m^3	3.00	6.00	18.00	3,251.01	**58,518.18**
	2. Formwork	m^2	32.00	6.00	192.00	648.75	**124,560.00**
	3. Rebar	kg	620.00	6.00	3,720.00	63.30	**235,476.00**
13	Footing Pad (1.2*1.2)						
	1. Concrete	m^3	1.20	27.00	32.40	3,251.01	**105,332.72**
	2. Formwork	m^2	4.00	27.00	108.00	648.75	**70,065.00**
	3. Rebar	kg	86.00	27.00	2,322.00	63.30	**146,982.60**
14	Footing Pad(2m*2m)						
	1. Concrete	m^3	3.20	13.00	41.60	3,251.01	**135,242.02**
	2. Formwork	m^2	7.00	13.00	91.00	648.75	**59,036.25**
	3. Rebar	kg	305.00	13.00	3,965.00	63.30	**250,984.50**
	Total Construction Cost						**14,969,500.71**
	Total Construction Cost/1.15					**13,016,957.14**	

Appendix 4: Journal Manuscript

Critical Success Factors for Industrialized Building System Implementation for Mass Housing Projects in Addis Ababa

Henok Sime Haile[1], Denamo Addissie Nuramo, (PhD)[2]

[1]*Masters program Student in construction management at Addis Ababa University: Ethiopian Institute of Architecture, Building Construction and City Development (EiABC),* hefa2001@gmail.com

[2]*Assistant Professor at the Addis Ababa University, Chair holder, Construction Materials and Engineering Design Ethiopian Institute of Architecture, Building Construction and City Development (EiABC),* denamo.addissie@eiabc.edu.et

ABSTRACT

Industrialized Building System is defined as a construction method and development approach in which components are fabricated on or off site, transported, and assembled with minimal additional work on site. It is an engineering innovation to prevent most compelling impediments of ordinary strategies of development in order to boost project performance. The system has a significant potential that can be harnessed if utilized for projects like mass housing. Responding to the challenge and in recognition to the potential advantages of this construction technique, the purpose of this paper is to present prioritized rank of critical success factors that affect a successful implementation for mass housing project in terms of their influence on implementation. The paper identifies and ranks eight critical success factors that directly influences implementation and further expanded into 31 sub-factors. Survey research methodology used in the research where questionnaires and interview survey study are carried out and Analytic Hierarchy Process analysis method is used to prioritize identified critical success factors. The finding rank cost factors first as the most critical factor for IBS implementation followed by knowledge and skill factors. Government policies and regulations factors ranked third, technology factor fourth, supply chain and market factor ranked fifth and management factors at sixth. Production and logistics factors ranked seventh and an integration factor is ranked eighth. In line with the findings the research recommends the housing construction industry change its conventional on-site approach to industrialized building system construction method, and for a successful implementation respective stakeholders need to play more roles unlocking the critical success factors such as financial incentives, knowledge and skill development and setting regulation and standard to streamline the implementation in housing project life cycle.

Key Words: Industrialized Building System, Critical Success Factor, Precast Concrete

1. Introduction

The construction industry by its nature is unique, dynamic, intricate and capital intensive for its realization. Output of construction process can be affected by the technique of construction and technology utilized. The construction industry in developing countries faces challenges of different kinds, often characterized by time delay, cost overrun and below standard quality construction. In this regard, shortage of residential housing can be cited as a critical issue in major cities of Ethiopia, particularly in urban centres including Addis Ababa.

Given numerous advantages to the built environment of Industrialized building systems (IBS) based on previous studies, including the reduction of onsite greenhouse gas emissions, and the improvement of construction schedule and product quality. However, the extensive demand of pre-project planning and coordination of stakeholders in the sector have altogether hindered the application of this method.

Industrialized Building System is a term used to describe the combination of building component automation and preassembly. IBS elements are fabricated off-site and require limited on-site work once installed. This translates to shortened project completion times, increased efficiency, less waste, fewer accidents, and lower total construction costs. Despite the fact that industrialized building systems have advantages over traditional construction methods in terms of cost savings, less reliance on trained labour, quality control, environmental friendliness, and less reliance on weather delays, the utilization of IBS specially for housing project is limited in Addis Ababa. First, there is a lack of awareness of the potential of IBS, which necessitates a shift in the mindset of construction industry players that IBS is far superior to traditional construction in the long run, which is exacerbated by a lack of technical know-how from production to erection and relatively high production costs, and second, there appear to be insufficient push factors and incentives from governments and policymakers to attract private stakeholders to invest in the production of IBS in order to harness the potential advantage of IBS (Birhanu, 2020).

Over the last few decades, Addis Ababa's city administration capacity to deliver affordable housing has been severely strained by urbanization and unprecedented population growth. The city administration launched the program to alleviate this housing shortage called Integrated Housing Development Program 'condominium housing project' in 2004 as part of its inner-city upgrading development (UN-Habitat, 2017). Despite the efforts, the process of finalizing and transferring housing units to beneficiaries took much longer, demonstrating that development delays have become a significant challenge for integrated housing development program especially in Addis Ababa (Bekele, 2018). The current dominant type of housing construction system in Ethiopia is a conventional system, which is incommensurable with rising housing demand, leading to negative ramifications on housing construction such as lengthy development periods, wastages, increased costs, high embedded energy, etc., which all significantly contribute to the challenge of price unaffordability for the low-income section of the population. The objective of tis paper is to present a prioritized rank of the critical success factors that would enable the utilization of IBS for mass housing development projects in Addis Ababa.

2. Construction Industrialization

Industrialization entails the mass production of a wide range of products, including elements that can be used by a wide number of stakeholders, each with their own goals that are distinct from the producers. The central theme behind construction industrialization is that the traditional building process should be restructured to focus on mass production of components for assembly rather than planning for most, if not all, processes to be completed on the job site. Site production is a feature of traditional construction, in which production takes place at the final location of the product to be developed. Construction industrialization can be viewed as a structural technique of removing or dramatically reducing on-site operations (Koskela, 2003).

Construction industrialization entails the widespread usage of prefabricated factory-finished large-scale elements and the transformation of production into a mechanized and continuous-flowing process of assembling and installing prefabricated assemblies and parts in buildings and structures. Industrialization has demonstrated a strong ability to lower costs, improve quality, and make complex products accessible to the vast majority of people. A combination of several technologies can be incorporated into the construction process to circumvent the current issues that define the construction industry and to transform design, manufacturing, and construction processes. Construction industrialization is becoming the norm, with extensive use of advanced technology in activities ranging from off-site prefabrication to the transformation of construction into a mechanized and continuous process of assembly and installation of these prefabricated assemblies and parts.

2.1. Industrialized Building System

The IBS is not a new concept in the construction industry; in essence, the growing demand for affordable housing, rising construction costs, and a lower productivity rate have led to the construction industry turning to the immense benefits of an industrialized building system. Despite its advantages, the implementation of industrialized construction systems has been gradual, owing in part to a lack of understanding and coordination among the parties involved (Oglesby, 1989).

The terms IBS off-site manufacturing and modular construction are frequently used interchangeably, and their clear-cut definitions are heavily dependent on user experience and understanding, which varies from country to country. The term was coined to denote a departure from the traditional paradigm of prefabricated systems. Though many prefabrication and industrialization terms are still in use, Industrialized Building System (IBS) has emerged as a term to represent those concepts.

The six standards characteristics IBS are transportation, production and assembly technique, mass-production, onsite fabrication, standardization, well-thought-out planning, and process integration (Badir YF, 2002). While almost all literatures emphasized the importance of offsite technology or factory production in IBS, they also emphasized the use of onsite technologies in IBS (Shaari, 2003). Building components which are often used in the IBS projects include walls, floors, beams and staircases (Abdul, 2005).

2.2. Industrialized Building System for Mass Housing

The concept "mass-housing" refers to a uniform method to home production that has been used to accommodate the rapidly increasing housing demand in most developing economies (Ahadzie, Proverbs, & Olomolaiye, 2008). The concept of mass production inspired the mass housing (Karji, Woldesenbet, Khanzadi, & Tafazzoli, 2019). It referred to standardized house-units, built within the same project scheme, without consideration for any particular consumer, and often in the same neighbourhood (Kwofie, Fugar, Adinyira, & Ahadzie, 2014).

Mass Housing projects have unique characteristics that make management substantially more difficult than 'one-off' conventional projects, needing a particular, one-of-a-kind management style and competence in their implementation (Turner, 2003) (Thorpe, 1999); (Ahadzie, Proverbs, & Olomolaiye, 2008); (Turner, 2003). Generally, mass housing projects share the following two features, the first feature is its physical attributes, such as the project's scale, the second is the nature of the designs, which is a repeating scheme, and the third is logistical complexity, which is carried out in multiple locations. In this regard, all attempted definitions of mass housing draw on the physical attributes of mass housing projects' inherent impact on performance, including Cost, Time, and Quality, in an attempt to achieve success in developing countries, forcing the construction industry to seek out more rational construction methods.

In this study, mass housing is viewed as residential buildings, proposed and developed in standard multiple units on a substantial scale entirely by a government or in synergy with private concerns for citizens to rent, own-occupy or outright purchase. Compared to IBS, the conventional construction processes have limited the types of buildings, materials, and technologies that can be used. Industrialized construction, on the other hand, can offer greater versatility in terms of creating varieties, materials, and techniques which in turn individual freedom of choice will be expanded as a result. Addis Ababa city administration operates a housing development program to meet the significant demand for affordable housing induced by the country's rapid urbanization, particularly among low and middle-income households. The government operated integrated housing development program main goal is to address the housing supply challenges in AA with a construction of affordable low-cost mass housing units. The construction technique used in IHDP project is dominantly a conventional construction technique with cast in-situ concrete for structural members and precast ribbed slab for flooring and masonry hallow concert blocks for external enclosure and internal partition wall. Despite Government efforts, housing units under construction often took longer than planned completion period associated with the method of construction used which is a conventional construction technique, which in turn affect the target to achieve the required level of demand. (Zerayehu S. W., 2015).

3. The Critical Success Factors for IBS Implementation

IBS is one alternative construction strategy that has the potential to shift the existing traditional construction industry's tendency toward a more systematic approach to the manufacture of construction materials and the construction process. To ensure the success of IBS implementation in the construction industry and the transformation from conventional to IBS, tremendous attention should be paid to several critical areas that are critical to attaining a transformation, and action must be taken to identify the factors that may influence IBS implementation in order to benefit and profit from the system.

To understand the concept used in this paper, this section will explain and discuss key concepts, definitions and previous studies related to the research investigation. From a compressive literature review undertaken to identify the factors that generally influence IBS implementation, 31 critical factors which further categorized in 8 categories are summarized as follow:

3.1. Knowledge and Expertise Factors

A lack of knowledge and skill in the field of IBS construction would result in financial aspects that concern the cost of construction. Architects, contractors/producers, developers, and practitioners had a substantial impact on the success of innovative modern prefabricated housing schemes because of their contributions to the development process and their participation in decision-making (Palmer, 2003). Some of the critical factor identified in these categories includes; Training & Education: (Nawi M. N., 2015), Labour skill: (Goodier, 2004), Skill of Expertise: (Pan W. G., 2008).

3.2. Management Factors

Effective management contributes favourably to construction performance since it can be efficiently applied and monitored during each step of the project. In an industrialized building system, management factors are the niche of the entire supply chain system (Bari, 2012). The following management factors are considered the critical influencing factors in the deployment of IBS. Factors in this category includes; Good working collaboration: (Kamar K. A., 2010), Effective communication channel: (Pan W. G., 2007), Team members involved in the design stage: (Blismas, 2007), extensive planning and scheduling: (Cheung, 2012), Risk management: (Hassim, 2009), On-site management: (Luo, 2015), Technical aspects: (Luo, 2015), and Top-down commitment: (Harjeev, 2011).

3.3. Supply Chain and Market Factors

Supply chain management is the management of a system of interconnected companies involved in the final provision of product and service required by end customers. In terms of competitiveness and efficiency, the fragmented construction sector has a significant influence on the IBS supply chain. IBS requires a high level of supply chain coordination and integration across the design, manufacturing, and construction stages. The following management factors are considered the critical influencing factors in the deployment of IBS; Management of supply chain and logistic: (Nagurney, 2006), Procurement Management: (Morledge, 2006), Business and Marketing strategy and Payment Issues: (Dzulkalnine, 2017).

3.4. Integration Factors

The construction industry's distinct character, which is centred on one-time projects and temporary partnerships, has a significant influence on the flow of communication and coordination among team members, contributing to a contentious relationship. Some of the factors includes; Integration of Resources: (Arashpour, 2018), Team Integration: (Nawi M. L., 2011), and Integrated Processes Assessment: (Yunus, 2012).

3.5. Technology Factors

Technology plays an important role within a project team as a medium or effective instrument for organizing work, fostering participation, and communicating information. The usage of appropriate technology is crucial when it comes to developing an organization's structure in order to garner successful integrated teams (Koskela, 2003). The critical factors in this aspect includes; Utilization of Software: (Kamar K. A., 2010) and Information Communication Technology: (Ikechukwu O., 2011).

3.6. Cost Factors

Cost is certainly a critical determinant in any business venture, especially in the construction industry. The following are some of the cost factors that impact IBS system adoption includes; Initial investment cost: (Samaras, 2013), Operational costs: (Ikechukwu O., 2011) & Cost Estimation Models: (Shamsuddin, 2015).

3.7. Government Policies and Regulation

The most crucial aspect in enabling construction companies to operate together in an integrated and collaborative manner is government policies (Nawi M. N., 2015). Government policies must always be harmonized with the industry's shared vision in order for effective decision-making to materialize. Some of the factors includes; Government Policies, Regulations and Standards (Modular Coordination): (Warszawski, 1999).

3.8. Production and Logistics

Some of the critical factor in this category includes; Facilities (Level of Automation): (Warszawski, 1999), Transportation: (Haas, 2001), Modularization (Standardization): (Hashim, 2011), Factory Location (Azman M.N.A., 2012) and Production Capacity.

4. Methodology

To achieve the objective of this paper, the research process was undertaken in two phases. In phase one, a systematic review was performed in order to collect and obtain detailed evidence for the impact of the critical success factors for IBS implementation. The systematic review approach was adopted based on a study by (Xiao Y. and Watson, M., 2017), which outline the six essential steps of conducting a systematic review. The process follows the following six steps;

Step 1: ***Identifying Keywords for Review:*** Keywords relevant for the systematic review were identified. A total of 6 most appropriate keywords were identified and used to fulfil the requirement of the study. The 6 keywords are "IBS", "Industrialized Building System", "pre-fabrication", "modern method construction", "off-site construction", and "industrialized building system (IBS)".

Step 2: ***Preliminary Search:*** Search was done using all the keywords obtained from the first step. The search was made based on the subject area of engineering as IBS is mainly an engineering method of construction innovation. Goggle® search engine is used to generate search results from keywords identified in previous step. In Scopus, the search is conducted from March, 2020-July, 2021 considering 'Title/Abstract/Keywords' and a total of 127 documents are generated during the process.

Step 3: ***Assessing the Quality of the Studies:*** Results generated through step 2 were further filtered to obtain the most suitable articles in order to achieve the objective.

Step 4: ***Selecting Data Source:*** Specific data source was selected from the 127 documents generated from step 2. Total of 83 documents were selected to be synthesized to obtain factors that influence performance of IBS project.

Step 5: ***Summarizing the Evidence:*** All 83 total filtered documents were then synthesized and grouped into themes consisting of what factors were the articles mostly mentioned or highly discussed. From total of 83 articles, 44 correspond towards factors influencing IBS project performance. The remaining 39 articles were studies that were not directly related towards IBS project performance.

Step 6: ***Interpreting Findings, Includes Synthesizing:*** Articles obtained were then interpreted and synthesized. As a result, 31 factors were classified and categorized in to 8 main factor categories under the theme of 'critical success Factors influencing IBS Implementation. The 31 factors were then described in detail of what and how does the factor itself influence implementation of IBS. The critical success factor identified is Coded for analysis purpose and presented in Table 1.

In phase two, Primary data was collected using two survey tools. Questionnaires are issued to professionals, institutions, and prefabricated materials manufacturers who have experience working on IBS-related projects based on pre-determined selection criteria. The questionnaires distributed and semi-structured interviews are conducted among sample selected using non-probable purposive sampling. The study population consists of construction professionals both in public and private sectors, institutions and manufacturers. The first group includes professionals (architects, civil engineers and construction managers) with education level, BSC degree and above, 10 years work experience out of it 5-year direct involvement in IBS and housing projects). In the second category (contractors, consultants, government officials and project owners) with 15 years' experience and 5-year direct involvement with in the mass housing sector and IBS. The third category includes private and government owned IBS manufacturers. Surveys were sent to 15 participants in category one, 20 participants in category two and 9 manufacturers. A total of 44 participants were involved with an acceptable response rate (Nultly, 2008) of approximately 82%.

The questionnaires were to ask them for comparing the importance of each CSF indicator to another one and compare the importance of each criterion under each indicator to the other one at the same indicator. The scale used in this questionnaire is presented in Table 2, a sample questionnaire is shown in Figure 1.

Table 1: *List of critical success factors*

Category	Critical Success Factors (CSF)	Code	Category	Critical Success Factors (CSF)	Code
Knowledge Factor (CSF I1)	Training & Education	**(CSF 1)**	**Production And Logistics (CSF I8)**	Facilities (Level of Automation)	**(CSF 16)**
	Labour skill	**(CSF 2)**		Transportation	**(CSF 17)**
	Skill of Expertise	**(CSF 3)**		Modularization(Standardization)	**(CSF 18)**
				Factory Location	**(CSF 19)**
Technology Factor (CSF I5)	Utilization Of Software	**(CSF 4)**		Production Capacity	**(CSF 20)**
	Information Communication Technology (ICT),	**(CSF 5)**			
Integration Factor (CSF I7)	Integration Of Resources	**(CSF 6)**	**Cost Factor (CSF I4)**	Initial Investment Cost	**(CSF 21)**
	Team Integration	**(CSF 7)**		Operational Costs	**(CSF 22)**
	Integrated Processes Assessment	**(CSF 8)**		Cost Estimation Models	**(CSF 23)**
Government	Policy Framework	**(CSF 9)**	**Management**	Good working collaboration	**(CSF 24)**

Policies and Regulation (CSF I6)	Regulations	**(CSF 10)**	**Factors (CSF I3)**	Effective Communication Channel	**(CSF 25)**
	Standard /Modular Coordination /	**(CSF 11)**		Team Members Involvement During the Design Stage	**(CSF 26)**
				Risk management	**(CSF 27)**
Supply Chain and Market Factor (CSF I2)	Management of supply chain and logistic	**(CSF 12)**		Extensive Planning and Scheduling	**(CSF 28)**
	Procurement Management	**(CSF 13)**		Top-down commitment	**(CSF 29)**
	Business and Marketing strategy	**(CSF 14)**		On-Site Management	**(CSF 30)**
	Payment Issues	**(CSF 15)**		Technical Factor	**(CSF 31)**

After identifying and categorizing these factors as critical success factors, the researcher used another questionnaire based on Fuzzy AHP techniques, to compare these factors and prioritize them from the most critical to the less critical.

Table 2: *Fundamental Scale for pairwise comparison/ Saaty's scale/: Source: (Saaty R. , 1987)*

Intensity of Importance	Definition	Explanation	Reciprocal
1	Equal importance	Two elements contribute equally to the objective	**1**
3	Moderate Importance	Experience and judgement moderately favour one element over the other	**1/3**
5	Strong Importance	Experience and judgement Strongly favour one element over the other	**1/5**
7	Very strong Importance	One element is favoured very strongly over another	**1/7**
9	Extreme Importance	one element favouring highest possible order over another	**1/9**
2,4,6,8	Intermediate values b/n the two judgments	When compromise is needed	**1/2,1/4,1/6,1/8**

INTEGRATION FACTOR [CSF (i7)]																		
CSFs	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**CSFs**
Integration Of Resources	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Team Integration
Integration Of Resources	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Integrated Processes Assessment
Team Integration	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Integrated Processes Assessment
SUPPLY CHAIN & MARKET FACTOR [CSF (i2)]																		
CSFs	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	CSFs
Management Factors	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Procurement Management
Management of supply chain and logistic	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Business and Marketing strategy
Management of supply chain and logistic	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Payment Issues
Procurement Management	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Business and Marketing strategy
Procurement Management	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Payment Issues
Business and Marketing strategy	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Payment Issues

Figure 1: Sample Questionnaire distributed for pair wise comparison using Saaty's scale

5. Analysis and Result

The analytic hierarchy process (AHP), which first proposed by Saaty, AHP analysis method is adopted as an analysis tool for this research since, the method allows categorizing the different criteria and factors in to sub-categories and can generate a pairwise comparison of each factor which eliminates a subjective bias in decision making during prioritization to reach at optimal result of the analysis. AHP is also applicable for the analysis of both qualitative and quantitative data, which is the research approach adopted in this research. The method also assures the validity of the analysis with a consistency Index that can be generated from matrix.
Following the collection of critical success factors for implementing IBS, data analysis is performed. The analysis process was undergone in two stages; the quantitative data was analysed using Expert Choice® software. The software is chosen, since it incorporates intuitive graphical user-friendly interface, automatic calculation of priorities and inconsistencies and several ways to process a sensitivity analysis. The analysis process is consisting of three stages; First stage is objective tree development shown on Figure 2, followed by data entry to Expert Choice® software as shown on Figure 3 and finally Synthesizing the priority rank and checking for consistency (The inconsistencies are acceptable, and a reliable result may be expected from the AHP if CI<0.1 (Saaty T. , 1980)). The qualitative data collected is analysed in a simple statistical analysis to compute the response rate and obtain the priority rank of the critical success factors

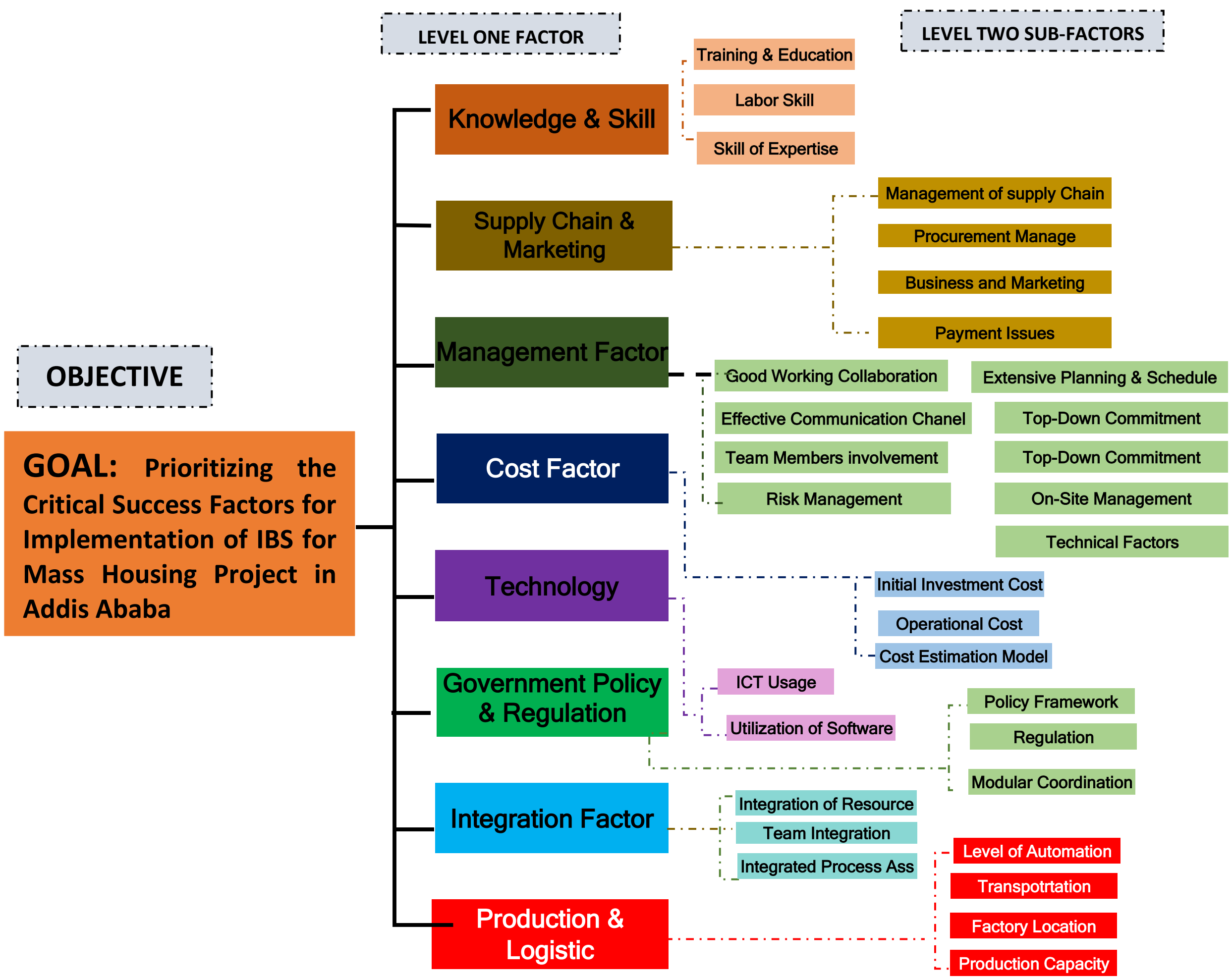
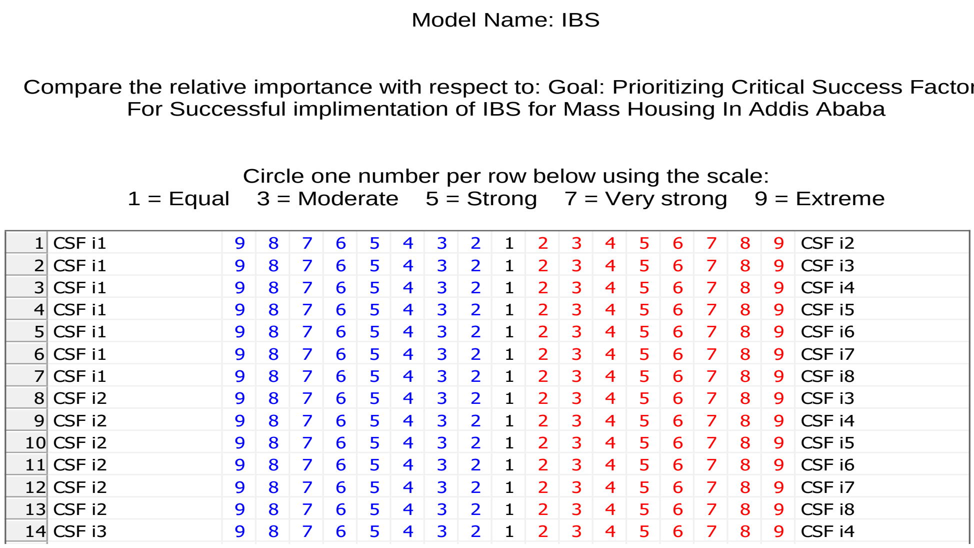


Figure 2: The Analytical Hierarchy Process structure for 8 CSF at level one and 31 CSF at level two



Model Name: IBS

Compare the relative importance with respect to: Goal: Prioritizing Critical Success Factors For Successful implimentation of IBS for Mass Housing In Addis Ababa

Circle one number per row below using the scale:
1 = Equal 3 = Moderate 5 = Strong 7 = Very strong 9 = Extreme

1	CSF i1	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	CSF i2
2	CSF i1	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	CSF i3
3	CSF i1	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	CSF i4
4	CSF i1	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	CSF i5
5	CSF i1	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	CSF i6
6	CSF i1	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	CSF i7
7	CSF i1	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	CSF i8
8	CSF i2	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	CSF i3
9	CSF i2	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	CSF i4
10	CSF i2	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	CSF i5
11	CSF i2	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	CSF i6
12	CSF i2	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	CSF i7
13	CSF i2	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	CSF i8
14	CSF i3	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	CSF i4

Figure 3: Data Entry Format on Expert Choice Software

5.1. Priority Ranking of the Eight CSF from AHP Analysis

The eight critical success factors identified in the literature investigations are prioritized according to their priority vector resulted from respondents' data analysis. The result is shown in Table 3 and Figure 4. The result also shows an overall consistency of (Index)=0.03 which is within an acceptable limit <0.1

Table 3: *Ranking of the Eight CSF*

Code	The Eight CSF (Level One)	Priority Vector (%)	Priority Ranking
CSFi_4	**Cost Factor**	**19.1**	**1st**
CSFi_1	**Knowledge And Skill Factor**	**14.4**	**2nd**
CSFi_6	**Government Policies & Regulation**	**13.8**	**3rd**
CSFi_5	**Technology Factor**	**11.8**	**4th**
CSFi_2	**Supply Chain & Market Factor**	**10.9**	**5th**
CSFi_3	**Management Factors**	**10.4**	**6th**
CSFi_8	**Production & Logistics**	**10.0**	**7th**
CSFi_7	**Integration Factor**	**9.6**	**8th**

The analysis put the cost factor as the most critical factor for a successful implementation of IBS for mass housing project, with 19.1% vector factor. Particularly, Initial investment cost, which includes the cost required to erect production facility cost incurred to install Machinery, Equipment and Technology Costs. Knowledge Factor comes second in the priority ranking with priority vector value 14.4%. Due to their contribution to the development process and role in the decision-making process, addressing the knowledge gap and shortage of expertise within the area of IBS implementation including such architects, contractors, production companies, developers, and practitioners has a significant impact on the success of IBS for innovative modern large scale produced housing projects.

A critical success factor ranked third is a factor related with government policies and regulation with priority vector value 13.8%. This factor is considered as one of the most important factors in enabling the IBS in construction process. Because firms and industries usually align their strategies with government policy, favourable government policy influences the development of new techniques, notably in the construction industry. In addition, participants' response for the interview conducted stressed, for successful IBS implementation governments supportive policy mechanisms for the construction manufacturing industry such as developing capacity and capability of the private sector, strengthening research and development and commercialisation, financial assistant and various regulatory measures are considered as critical enabling factors.

Technology Factors with priority vector value 11.8%, which ranked in fourth place, play an essential role as a medium or proper method for coordinating operations. In this case, technology may serve as a communication channel between team members, allowing them to better integrate their operations and keep the entire team up to date on design information in order to coordinate precise design and construction processes, costs, and timelines in a project. The effective use of software, in particular, significantly aids communication and coordination between parties, resulting in a successfully integrated project team

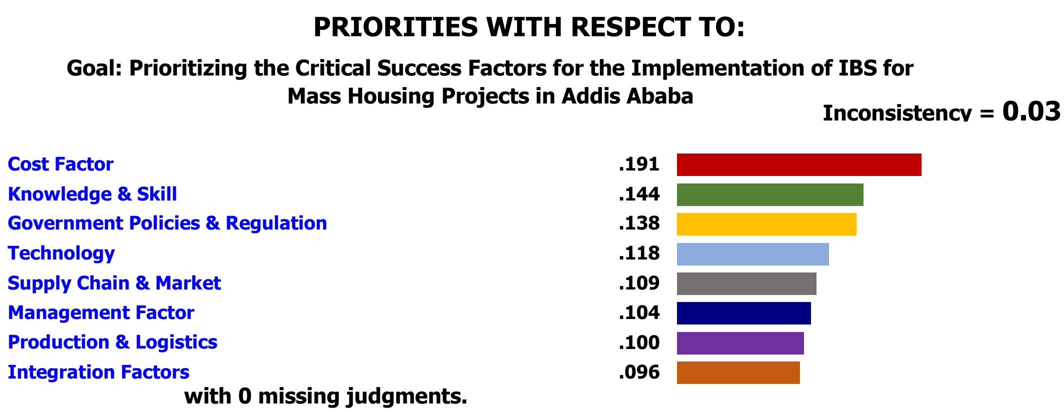


Figure 4: Overall Priority Graph for Prioritized Eight CSFs and Consistency Index

Supply chain &Market Factor with priority vector value 10.9% and Management Factor, with priority vector value 10.4% is ranked fifth and sixth for IBS implementation success. The IBS requirement for a high level of coordination and integration of supply chains from design, manufacturing, and construction phases influences its performance in terms of supply chain and market factor. In an industrialized building system, management factors are also the niche of the whole supply chain system. According to the study result presented in Table 4, extensive planning and scheduling, as well as on-site management, are the most important influential factors in the implementation of IBS. The last two factors ranked seventh and eighth form the AHP analysis result are Production and Logistics with priority vector value 10.0% and Integration Factor with priority vector value 9.6% respectively as shown on table 3. Factory location with respect to construction sites is ranked high in the factor priority list. The location of production facility is considered as one of the factors for the successful implementation of IBS.

5.2. The Pairwise comparison of the thirty-one CSF (Level Two)

Pairwise Comparisons and Global Ranking of the thirty-one CSF identified in the literature investigations is prioritized according to their priority vector resulted from respondents' data analysis. The result is shown consecutively in Table 4 to 11 and Figure 5. The result also shows an overall consistency of (Index)=0.05 which is within an acceptable limit <0.1

Table 4: *Pairwise Comparisons and Global Ranking of CSF /**Cost Factors**/*

The CSF (Level One) **CSFi_4**	**Code**	**The Local Ranking of Alternative CSFs**	**Priority Ranking** *[pairwise comparisons]*	**Priority Vector (%)**	**Priority Ranking**
		(Level Two)	*(Local)*		*(Global)*
COST FACTOR Priority Vector = 19.1%	**CSF-21**	Initial Investment Cost	**1st**	7.1	**1**
	CSF-22	Operational Costs	**2nd**	2.5	**22**
	CSF-23	Cost Estimation Models	**3rd**	1.0	**31**

Table 5: *Pairwise Comparisons and Global Ranking of CSF /**Knowledge Factors**/*

The CSF (Level One) **CSFi_1**	**Code**	**The Local Ranking of Alternative CSFs**	**Priority Ranking** *[pairwise comparisons]*	**Priority Vector (%)**	**Priority Ranking**
		(Level Two)	*(Local)*		*(Global)*
KNOWLEDGE FACTOR Priority Vector = 14.4%	**CSF-21**	Training & Education	**1st**	5.4	**2**
	CSF-22	Labour skill	**2nd**	2.9	**18**
	CSF-23	Skill of Expertise	**3rd**	2.4	**23**

Table 6: *Pairwise Comparisons and Global Ranking of CSF /**Government Policies & Regulation**/*

The CSF (Level One) **CSFi_6**	**Code**	**The Local Ranking of AlternativeCSFs**	**Priority Ranking** *[pairwise comparisons]*	**Priority Vector (%)**	**Priority Ranking**
		(Level Two)	*(Local)*		***(Global)***
GOVERNMENT POLICIES & REGULATION Priority Vector = 13.8%	**CSF-9**	Policy Framework	**1st**	5.2	**3**
	CSF-11	Standard /Modular Coordination /	**2nd**	5.1	**4**
	CSF-10	Regulations	**3rd**	3.8	**8**

Table 7: *Pairwise Comparisons and Global Ranking of CSF /**Technology Factors**/*

The CSF (Level One) **CSFi_5**	**Code**	**The Local Ranking of Alternative CSFs**	**Priority Ranking** *[pairwise comparisons]*	**Priority Vector (%)**	**Priority Ranking**
		(Level Two)	*(Local)*		*(Global)*
TECHNOLOGY FACTOR Priority Vector = 11.8%	**CSF-4**	Utilization Of Software	**1st**	4.4	**5**
	CSF-5	Information Communication Technology (ICT),	**2nd**	1.8	**29**

Table 8: *Pairwise Comparisons and Global Ranking of CSF /**Supply Chain & Market Factors**/*

The CSF (Level One) **CSFi_2**	**Code**	**The Local Ranking of Alternative CSFs**	**Priority Ranking** *[pairwise comparisons]*	**Priority Vector (%)**	**Priority Ranking**
		(Level Two)	*(Local)*		*(Global)*
SUPPLY CHAIN AND MARKET FACTOR Priority Vector = 10.9%	**CSF-12**	Management of supply chain & logistic	**1st**	4.1	**6**
	CSF-13	Procurement Management	**2nd**	3.4	**13**
	CSF-14	Business and Marketing strategy	**3rd**	2.9	**17**
	CSF-15	Payment Issues	**4th**	1.8	**28**

Table 9: *Pairwise Comparisons and Global Ranking of CSF /**Management Factors/***

The CSF (Level One) CSFi_3	Code	The Local Ranking of Alternative CSFs	Priority Ranking [pairwise comparisons]	Priority Vector (%)	Priority Ranking
		(Level Two)	*(Local)*		*(Global)*
MANAGEMENT FACTORS Priority Vector = 10.4%	**CSF-28**	Extensive Planning and Scheduling	**1st**	3.9	**7**
	CSF-30	On-Site Management	**2nd**	3.7	**9**
	CSF-26	Team Members Involvement During the Design Stage	**3rd**	3.0	**16**
	CSF-25	Effective Communication Channel	**4th**	2.9	**19**
	CSF-24	Good working collaboration	**5th**	2.8	**20**
	CSF-31	Technical Factor	**6th**	2.6	**21**
	CSF-29	Top-down commitment	**7th**	2.3	**24**
	CSF-27	Risk management	**8th**	2.1	**26**

Table 10: *Pairwise Comparisons and Global Ranking of CSF /**Production & Logistics/***

The CSF (Level One) CSFi_8	Code	The Local Ranking of Alternative CSFs	Priority Ranking [pairwise comparisons]	Priority Vector (%)	Priority Ranking
		(Level Two)	*(Local)*		*(Global)*
PRODUCTION & LOGISTICS Priority Vector = 10.0%	**CSF-19**	Factory Location	**1st**	3.7	**10**
	CSF-18	Modularization (Standardization)	**2nd**	3.2	**15**
	CSF-16	Facilities (Level of Automation)	**3rd**	2.1	**25**
	CSF-17	Transportation	**4th**	2.1	**27**
	CSF- 20	Production Capacity	**5th**	1.2	**30**

Table 11: *Pairwise Comparisons and Global Ranking of CSF /**Integration Factors/***

The CSF (Level One) CSFi_7	Code	The Local Ranking of Alternative CSFs	Priority Ranking [pairwise comparisons]	Priority Vector (%)	Priority Ranking
		(Level Two)	*(Local)*		*(Global)*
INTEGRATION FACTOR Priority Vector = 9.6 %	**CSF-6**	Integration Of Resources	**1st**	3.6	**11**
	CSF-7	Team Integration	**2nd**	3.6	**12**
	CSF-8	Integrated Processes Assessment	**3rd**	**3.2**	**14**

5.3. Priority Ranking of the Eight CSF from Interviews Analysis

The interview is conducted in person and the 34 respondents' response summarized as follows as shown in Table 12 and graphically on Figure 6. The result shows that, the result from the prioritization analysis using the AHP method complies with the response from the identification analysis. Knowledge, cost and government policy and regulation factors found to be critical for the successful implementation of IBS for mass housing construction. The exception from these analyses is the supply chain and market factor are included in top four factors. Whereas the other remaining factors are in perfect compliance with the AHP analysis result, even the ranking interims of respondents' response.

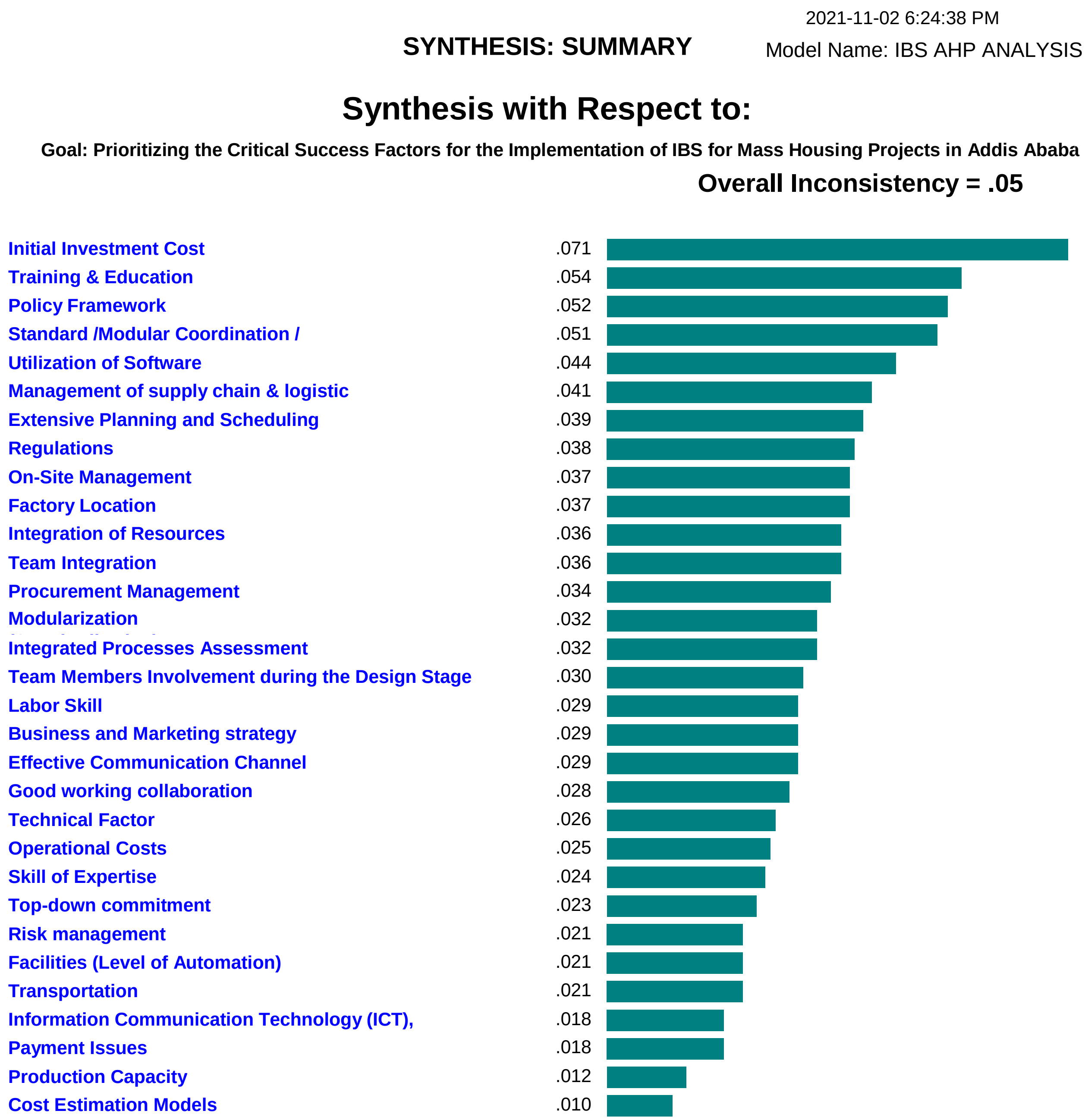


Figure 5: Overall Priority Graph for Prioritized thirty-one CSFs and Consistency Index

Table 12: *Analysis result of CSF Identification that affect IBS Implementation*

Responses for the CSF that Affect the Implementation of IBS (From 36 Respondents)	Respondents In %	CSFs
32 participants reply the knowledge and skills about The IBS system affects its implementation	**89.0%**	**Knowledge and skill**
28 participants believe that Supply Chain and Market Factor affects its implementation of IBS for mass housing projects	**87.5%**	**Supply Chain and Market**
26 responds, Management Factor affect IBS Implementation	**72.0%**	**Management**
30 participants reply Cost Factor Affects the IBS implementation	**83.0%**	**Cost**
32 respondents, similar to Knowledge factor believe the utilization of technology affects IBS implementation	**89.0%**	**Technology**
29 responds, Government Policies & Regulations affects IBS Implementation	**80.5%**	**Government Policies & Regulations**
26 participants reply Integration Factor Affects the IBS implementation	**72.0%**	**Integration**
27 responds, Production and Logistics Factor affects IBS Implementation	**75.0%**	**Production and Logistic**

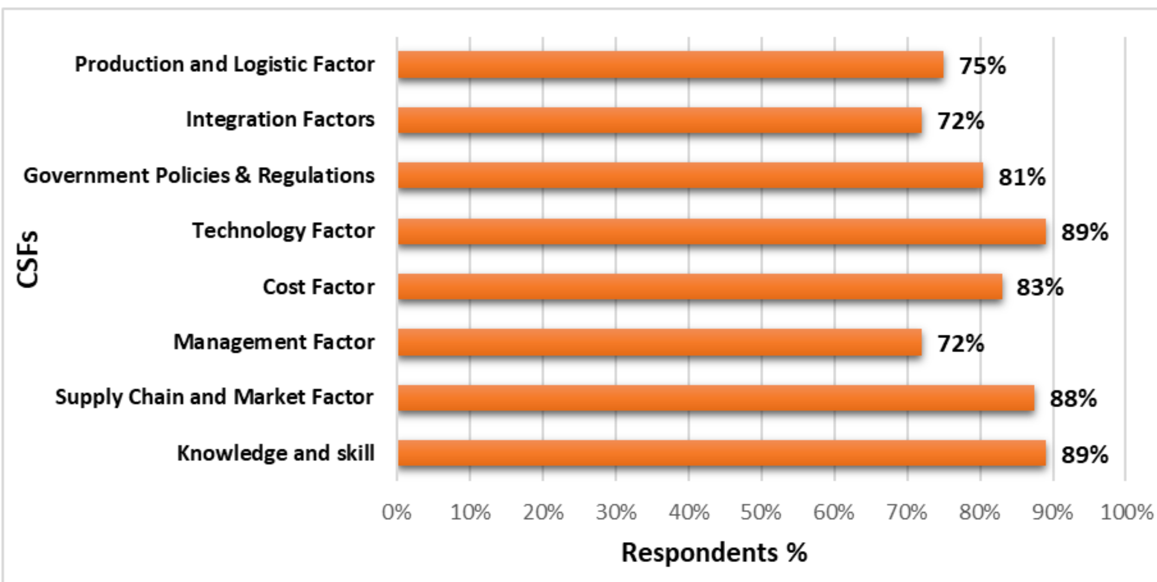


Figure 619: CSF That Affect IBS Implementation

6. Conclusion

Introduction of modern technologies as well as building system innovation has a significant potential to contribute towards many aspects of construction industry including improving constructions efficiency and sustainability. IBS has been proven in terms of its potential advantages such as minimizing construction wastage, reducing project cost, improving quality and reducing construction duration. To harness these potentials, this research has identified and analyzed those critical success factors for its implementation is very important in advance of selecting the system especially for large scale public projects like mass housing projects. The research undergoes a systematic review of studies to better understand IBS and underpin the factors influencing IBS success. The findings of the research present prioritized critical success factors based of their influence for its success.

The prioritized CSFs for implementing the IBS construction approach are ranked according to their relative importance. The cost factor is raked first, since IBS system adaptation necessitates mass production of building units, which demands high initial investment capital designated for machineries, technology, transportation, and the wages of skilled workers for the installation process, as well as financial problems emanating from building materials and land costs, have a significant impact on investors in the sector.

The second most influential factor is knowledge. Knowledge factors, such as the availability of well-educated human capital and expertise in IBS, play a significant role in the success of IBS initiatives. Government policies and regulations are placed third in terms of influencing or affecting IBS implementation, particularly modular coordination, which advocates for the formulation of a regulatory framework to apply uniform or universal measurement and component assembly techniques. Communication has a significant impact on the success of a construction project. Ranked fourth, efficiency of communication between stakeholders can facilitate the construction process commencing with design, manufacturing, and onsite installation are highly associated to the technology utilization factor. Failing to implement an effective communication channel can contribute to problems such as double handling, time delays, and data handling, all of which will have a detrimental impact on the cost of operation, quality, and total project duration. In the aspect of Supply chain and market factor ranked fifth, the IBS requirement for a high level of coordination and integration of supply chains from design, manufacturing, and construction stages affects its success.

The sixth-placed management factors are also the core of the whole supply chain system in the industrialized building system. According to the finding, extensive planning and scheduling, as well as on-site management are the most important influential factors in the implementation of IBS. The Production and Logistics ranked seventh. Especially factory location with respect to construction sites is ranked high in the factor priority list. Strategic location of production facility is considered as one of the factors for the successful implementation of IBS in relation to the project location. The last factor ranked eighth is an integration factor, process integration involving all subsystems, components, manufacturing and construction processes, and which all requires efficient management. IBS's success is influenced by the level of integration, both material and human resources.

Finlay, to harness the ranked potential advantages of IBS for mass housing construction in Addis Ababa, a comprehensive effort is required from stakeholder in the sector to address the prioritized success factors for a successful Implementation of IBS for mass housing construction. Despite its multifaceted ramifications, access to affordable and decent housing has long been a challenge in Addis Ababa. With the goal of meeting the overwhelming demand for housing, the adoption of IBS for mass housing is a prominent construction approach. In recognition to potential advantages of IBS, the housing construction industry needs an innovative construction approach to expedite the provision of dwellings in Addis Ababa.