International Journal for Multidisciplinary Research (IJFMR)

E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

Comparing Sustainability and Affordability: A Study of Prefabricated Versus Conventional Construction for Housing of Economically Weaker Sections

Karandeep Singh

Student, University School of Architecture and Planning, Guru Gobind Singh Indraprastha University

Abstract

This research aims to compare the sustainability and affordability of prefabricated housing with conventional construction for economically weaker sections (EWS) in India. The study analyzes the embodied energy, embodied carbon, and cost per functional unit for both construction methods. The findings reveal that prefabricated construction exhibits lower embodied energy and carbon emissions. However, it is observed that the initial cost of prefabricated construction is higher compared to conventional methods. The long-term cost implications are subject to specific project requirements and local conditions. This research highlights the potential of prefabrication in addressing the housing crisis and emphasizes the need for further exploration to optimize its cost-effectiveness. The outcomes contribute to the growing body of knowledge on sustainable housing solutions for EWS communities in India.

Keyword: Embodied Energy, Embodied Carbon, Cost analysis, Prefabricated housing, EWS housing

Chapter- 1

1. 1 Aim

The paper aims to compare the sustainability and affordability between prefabricated housing and Conventional Construction for economically weaker section.

1.2 Objective

The objective of this research are:

1. To understand the fundamentals of prefabricated housing and the current guidelines for EWS housing.
2. To understand the barriers, opportunities, performance and perception of sustainability and affordability in prefabricated housing
3. To calculate the life cycle assessment of different prefabricated materials as compared to conventional methods and to find which will be the best choice for EWS housing.

1.3 Limitations

Limitations of this study are-

1. Analysis has been done only on the material aspects of both construction systems.

2. Analysis has been done only on one functional unit of both the construction systems as specified.
3. For the analysis, only the materials of the structural system, flooring, roofing and walling have been taken into consideration for both the construction system.
4. The cost and energy required for transportation and Labour have not been taken into consideration.

1.4 Scope

Scope of this study are:

1. **Material analysis**- Focusing on the cost associated with the materials used in the construction of in situ and prefabricated construction systems. This includes the cost provided by the vendors for all the materials.
2. **Embodied Energy Analysis**: Assessing the embodied energy of the materials used in the construction of in situ and prefabricated construction systems. This involves quantifying the energy consumed during the extraction and manufacturing of the materials.
3. **Embodied Carbon Analysis**: Evaluating the embodied carbon emissions of the materials used in the construction of in situ and prefabricated construction systems. This entails quantifying the carbon dioxide and other greenhouse gas emissions associated with the production of the materials.

1.5 What is the need for this study?

In India, The economically weaker section (EWS) is the section of the society that belongs to the un-reserved category and has an annual family income of less than 8 lakh rupees. This category includes people that do not belong to the caste categories of ST/SC/OBC and who already enjoy the benefits of reservation.

India currently has 25 million homes, out of which 95% belong to EWS and LIG.
In 2015, the Indian government launched the Housing for All mission to provide affordable housing to the urban poor.

To achieve this goal, the government and private real estate developers have to launch large-scale affordable housing projects all over the country. However, the construction industry is facing issues with manpower shortages and rising costs of construction materials.
That is why this study is being done to find a better alternative to EWS housing from the conventional method of construction.

Currently, prefabricated construction accounts for only 2% of all Indian construction including large infrastructure like bridges and flyovers.

Prefabrication or off-site construction can offer great opportunities for both environmental and economic performance and hence is emerging as an attractive alternative to on-site construction. Although in the established markets the share of prefabrication in overall construction output remains strong, in many countries including India it remains in its infancy.

1.6 Methodology

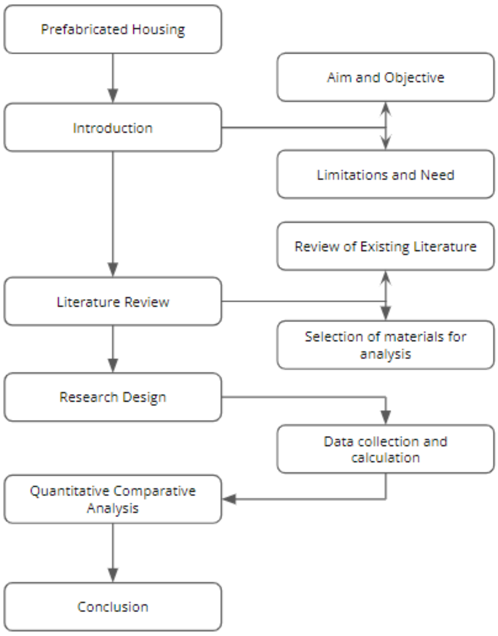

Figure 1 Methodology Flow Chart

Chapter- 2

2.1 Definition Of Prefabrication

Prefabrication refers to the process of manufacturing and assembling building components or entire structures in a factory or off-site location, before transporting and installing them at the final building site. This method is often used in construction to increase efficiency, and quality control, and reduce construction time and cost. Examples of prefabricated building components include wall panels, floor and roof trusses, and modular units for bathrooms and kitchens. Prefabrication is becoming increasingly popular in construction due to advancements in technology and the need for faster and more sustainable building methods.

2.2 Prefabricated Housing

Prefabrication is the practice of manufacturing the parts of an assembly in one location, ready for them to be assembled in another place.

- This consists of putting together a building from its components such as framework, posts, wall, beams etc. This technology has revolutionized the construction industry.
- The products are mass-produced in a plant. Once ordered, all the components are delivered to the site where they can be assembled in a few days.
- With prefabricated construction, the components are produced under optimal conditions which leads to a strong, standard and versatile structure.

2.3 Conventional Method Of Construction

The conventional method of construction in India refers to the traditional approach of building structures using materials such as bricks, concrete, stone, and steel, and involves on-site construction of the building using skilled labour and specialized equipment. This method involves creating the building's foundation, erecting the walls and floors, and installing the electrical, plumbing, and HVAC systems on-site. The process involves using local construction materials and techniques based on traditional practices and building codes and often influenced by the local climate and environment.

The conventional method of construction in India has been used for centuries and is still widely used today in both rural and urban areas. It is a proven method of construction that is reliable, durable, and can withstand the local climate and environmental conditions.

However, with the increasing demand for faster construction times and higher-quality buildings, the conventional method of construction is being complemented by modern construction techniques such as prefabrication, modular construction, and other innovative construction technologies. These methods offer several benefits such as faster construction times, reduced labor costs, and improved quality control, but they are not yet as widely used as the conventional method of construction in India.
The conventional materials used for the construction of EWS (Economically Weaker Section) housing in India include:

- **Concrete:** Concrete is a widely used material for construction due to its strength, durability, and affordability. It is commonly used for building foundations, walls, and floors.
- **Brick:** Bricks are a traditional building material in India and are commonly used for walls and foundations. They are durable and provide good thermal insulation.
- **Steel:** Steel is used in the construction of high-rise buildings, as it is strong, durable, and fire-resistant. It is also used in the construction of beams and columns.
- **Cement:** Cement is an important component of concrete and is used for binding other materials together. It is commonly used for the construction of floors, walls, and roofs.
- **Sand:** Sand is used as a filler material in concrete and mortar, as well as for plastering walls and ceilings.
- **Gravel:** Gravel is used in concrete for the construction of foundations, floors, and walls. It provides stability and helps to distribute weight evenly.
- **Wood:** Wood is used for the construction of roofs, doors, and windows, as well as for decorative purposes. It is a renewable and eco-friendly material.
- **Tiles:** Tiles are used for flooring and walls and are available in various materials, such as ceramic, porcelain, and marble.

The conventional technologies used for the construction of EWS (Economically Weaker Section) housing in India include:

- **Masonry construction:** This is the most common construction technology used for EWS housing. It involves the use of bricks, concrete blocks, or stones, and is popular due to its affordability and ease of construction.
- **Reinforced concrete construction:** Reinforced concrete is used in the construction of high-rise buildings due to its strength and durability. It involves the use of steel reinforcement bars and concrete, which are poured into moulds to create the building structure.
- **Precast construction:** This involves the manufacture of building components off-site, which are then transported to the construction site and assembled. Pre-cast construction is faster and more efficient than traditional masonry construction.

- **Steel frame construction:** This technology involves the use of steel frames to support the building structure. It is commonly used in high-rise buildings and provides good resistance to earthquakes and other natural disasters.
- **Composite construction:** Composite construction involves the use of two or more building materials in the construction of a building. For example, it may involve the use of steel frames with reinforced concrete.
- **Green construction:** Green construction involves the use of sustainable materials and technologies in the construction of buildings. It aims to minimize the environmental impact of construction while promoting energy efficiency and sustainability.

2.4 Types Of Prefabricated Housing

2.4.1 Manufactured Housing

Manufactured housing, also known as mobile homes, is a type of prefabricated housing that is built in a factory and transported to the site for installation. These homes are constructed on a permanent chassis and are designed to be transported to the site using wheels or a flatbed truck.

Manufactured homes are typically less expensive than traditional site-built homes and can be completed in a shorter amount of time. They are available in a variety of sizes and styles and can be customized to meet specific needs and preferences.

Manufactured homes are built to federal construction standards and must meet strict guidelines for safety and durability. They are also subject to state and local building codes, which vary depending on the location. In some cases, manufactured homes are placed on a permanent foundation and are considered to be real property, while in other cases they are treated as personal property and subject to different rules and regulations.

Manufactured housing is a popular option for those looking for an affordable and customizable housing solution, and can be an attractive alternative to traditional site-built homes. However, it is important to carefully consider the advantages and disadvantages of manufactured homes before making a decision.

2.4.2 Panel-built homes

Panel-built homes are a type of prefabricated housing that involves the construction of building panels in a factory and then transporting them to the site for assembly. These panels can include walls, roofs, and floors, and are typically made of wood, steel, or concrete.

The panel-built construction process offers several advantages over traditional on-site construction, including faster construction times, reduced material waste, and improved quality control. Panel-built homes can also be more energy-efficient and cost-effective than traditional homes.

The panels are typically built using computer-aided design (CAD) software, which allows for precise measurements and accurate construction. Once the panels are built, they are transported to the site and assembled using specialized equipment and skilled labour.

Panel-built homes can be designed to meet a variety of needs and can range in size from small modular homes to large commercial buildings. They can also be customized to meet specific aesthetic and functional requirements and can incorporate a variety of design elements and finishes.

Overall, panel-built homes are a popular option for those seeking a faster and more efficient construction process with customizable design options.

2.4.3 Modular Homes

Modular homes are a type of prefabricated housing that is built in a factory and transported to the site for installation. These homes are built in sections or modules, which are then assembled on-site to create a complete home.

Modular homes are built to the same building codes and standards as traditional site-built homes and offer several advantages over traditional construction methods. They are typically completed faster and more efficiently than traditional homes, with less material waste and improved quality control. They are also customizable, with a range of design options available to suit specific preferences and needs.

The modular construction process involves designing and building the modules in a factory, where they are subjected to strict quality control measures. The modules are then transported to the site and assembled using specialized equipment and skilled labour. Once assembled, the home is connected to the site utilities and finishes such as flooring, painting, and fixtures are completed.

Modular homes come in a range of sizes and styles, from small, single-story homes to large, multi-story homes. They can be designed to suit a variety of preferences and can include a range of features and finishes.

Overall, modular homes are a popular option for those seeking a faster and more efficient construction process with customizable design options. They offer a range of advantages over traditional construction methods and are becoming an increasingly popular choice for homeowners and developers alike.

2.5 History Of Prefabricated Housing

The history of prefabricated housing dates back to the 19th century when the concept of prefabrication was first developed. The idea was to build standardized parts of a structure in a factory and then assemble them on-site to create a complete building. The first prefabricated homes were built in the 1830s in England and were made of cast iron components.

In the United States, the first prefabricated house was built in the 1850s by a company called Manning Portable Cottage. These homes were made of wood and were shipped in sections to be assembled on-site. The concept became increasingly popular in the late 19th and early 20th centuries, with companies like Sears, Roebuck and Co. offering mail-order prefabricated homes that could be assembled by the homeowner.

During World War II, prefabricated housing was used to house soldiers and their families. The United States government developed a program called the Emergency War Housing Program, which produced more than 600,000 prefabricated homes between 1941 and 1945. After the war, many of these homes were sold to civilians and became popular as affordable housing options.

In the 1950s and 1960s, prefabricated housing continued to be popular, with the development of mobile homes and modular homes. These homes were built in factories and transported to the site for installation, offering a more efficient and affordable alternative to traditional site-built homes.

Today, prefabricated housing continues to be an increasingly popular option for those seeking affordable, customizable, and sustainable housing solutions. The industry has continued to evolve and innovate, with new technologies and materials allowing for even greater flexibility and efficiency in the construction of prefabricated homes.

2.6 Need For Prefabrication

The most commonly used method of prefabrication in building and civil engineering involves using prefabricated concrete and steel sections for repetitive components. On-site construction of concrete parts can be challenging due to the need for formwork and precise timing for pouring and setting.

By manufacturing concrete sections in a factory, moulds can be reused, and concrete can be mixed on-site without the hassle of transportation and pumping at a crowded construction site. Prefabricated steel sections also reduce costs and hazards associated with on-site cutting and welding. This approach is employed in various construction projects such as apartment blocks, housing developments, office buildings, warehouses, and factories.

The quality of prefabricated housing units has improved to the extent that they are indistinguishable from traditionally-built units. In civil engineering, prefabrication techniques save time, especially in projects like bridges and avalanche galleries where weather conditions limit construction time. Prefabricated bridge elements and systems offer several advantages, including shorter construction time, enhanced safety, reduced environmental impact, improved constructability, and lower costs. Furthermore, prefabrication helps minimize traffic disruptions caused by bridge construction. Even smaller structures like concrete pylons are often prefabricated.

2.7 Principles Of Prefabrication

The principles of prefabrication are focused on creating a more efficient and streamlined construction process while maintaining high levels of quality and consistency across all components.

2.7.1 Standardization

Prefabricated components are designed to be standardized, allowing for easy and efficient assembly on-site. This reduces construction time and costs and ensures consistent quality across all components.

2.7.2 Modular Design

Prefabricated components are often designed to be modular, meaning that they can be easily connected and configured in a variety of ways to create a wide range of building sizes and configurations.

2.7.3 Quality Control

Prefabrication allows for greater quality control, as components can be manufactured in a controlled factory environment with rigorous quality standards. This helps to ensure that each component is built to a high level of quality and consistency.

2.7.4 Speed of Construction

Prefabricated components can be manufactured in advance of on-site construction, reducing the overall construction time and minimizing disruptions to the surrounding area.

2.7.5 Cost-Effectiveness

Prefabrication can be a cost-effective construction method, as it reduces the amount of on-site labour required and minimizes material waste.

2.8 Parameters For Assessment Of Housing For Ews

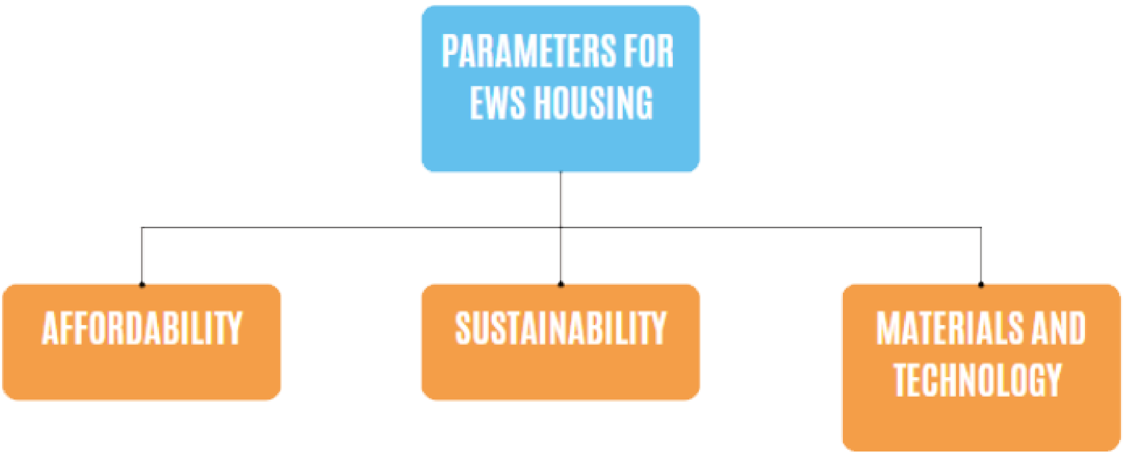

Figure 2 Parameters Flow Chart

2.8.1 Ews (Economically Weaker Section)

Economically Weaker Sections (EWS) is a term used in India to describe a specific group of people who belong to the lower-income bracket and are considered to be socio-economically disadvantaged. The government of India defines households with an annual income of up to Rs. 3 lakhs (approximately USD 4,000) as EWS households. These households typically struggle to access basic amenities such as housing, healthcare, education, and sanitation.

As per the Socio-Economic and Caste Census of India conducted in 2011, the average household size for

EWS households was found to be 4.5 persons. This means that on average, an EWS household in India comprises 4-5 individuals

As per the Socio-Economic and Caste Census of India conducted in 2011, there were 24.39 crore households in India, out of which 4.3 crore households (17.69%) were categorized as EWS. The same census also found that 95% of EWS households in India live in rural areas, while only 5% live in urban areas.

The states with the highest percentage of EWS households are Bihar (32%), Jharkhand (28%), and Chhattisgarh (26%).

2.8.2 AFFORDABILITY FOR EWS

Affordable housing for EWS (Economically Weaker Sections) in India refers to housing units that are designed and built specifically for low-income families who cannot afford to purchase or rent a house at market rates. These housing units are typically small in size and built with basic amenities, but they are safe, hygienic, and affordable for the targeted population.

The Government of India's affordable housing scheme, Pradhan Mantri Awas Yojana (PMAY), provides financial assistance to eligible EWS families to either purchase or construct a house or renovate their existing house.

Under the PMAY (Pradhan Mantri Awas Yojana), the affordable housing units for EWS families are required to meet certain specifications, such as:

- The carpet area of the house should not exceed 30 square meters (322 square feet).
- The house should have a toilet and a bathroom with running water.
- The house should have a kitchen sink.
- The house should be earthquake-resistant and built using durable materials.
- The house should have basic infrastructure such as electricity, water, and sanitation facilities.
- Although, there is no general guideline for the cost of construction of EWS housing, according to MoHUPA 2011, monthly EMI or rent shall not exceed 30-40% of the gross monthly income of the buyer**.**

The cost of affordable housing for EWS families under the PMAY scheme varies depending on the location and construction standards, but the government provides financial assistance to ensure that the houses are affordable for the target population

2.8.3 Sustainable Housing

Sustainable housing refers to the design, construction, and operation of housing that is environmentally responsible, socially inclusive, and economically viable. Sustainable housing aims to minimize the negative impact on the environment and promote the efficient use of resources while improving the quality of life for its residents.

In India, sustainable housing initiatives are gaining momentum due to the increasing awareness of environmental issues, the need for affordable housing, and the availability of sustainable building technologies. The government and private developers are investing in sustainable housing projects that integrate green building practices, renewable energy sources, and eco-friendly materials.

Some of the key features of sustainable housing in India are:

- ***Energy-efficient design***: Sustainable housing designs incorporate passive solar design techniques, such as orientation, insulation, and shading, to reduce energy consumption for heating and cooling.
- ***Use of eco-friendly materials***: Sustainable housing uses non-toxic, locally sourced, and renewable materials to reduce the carbon footprint of the building.
- ***Water conservation***: Sustainable housing includes water-efficient plumbing fixtures, rainwater harvesting, and wastewater treatment systems to conserve water.
- ***Renewable energy***: Sustainable housing incorporates renewable energy sources such as solar panels, wind turbines, and biomass systems to reduce dependence on fossil fuels.
- ***Social inclusion***: Sustainable housing initiatives focus on providing affordable and accessible housing for all, including low-income families, people with disabilities, and the elderly.
- ***Energy efficiency***: The housing should be designed to maximize energy efficiency, with features such as passive solar design, energy-efficient appliances, and renewable energy sources like solar panels.
- ***Sustainable materials***: The construction materials should be sustainable and eco-friendly, with a focus on using locally sourced, recycled, and low-impact materials.
- ***Green spaces***: The housing should include green spaces like parks, gardens, and playgrounds, which not only provide recreational space but also help improve air quality and reduce urban heat island effects.
- ***Access to public transportation***: The housing should be located in areas with good access to public transportation, reducing the need for private vehicles and promoting sustainable transportation.
- ***Waste management:*** The housing should have a waste management system in place, with a focus on reducing, reusing, and recycling waste.
- ***Community involvement***: The housing should involve the local community in the planning and design process, ensuring that the housing meets the needs of the EWS population and fosters a sense of community ownership.
- ***Disaster resilience***: The housing should be designed to be resilient to natural disasters such as floods, earthquakes, and cyclones, with features such as raised foundations, reinforced structures, and emergency management plans.
- ***Health and safety***: The housing should be designed to promote the health and safety of residents, with features such as proper ventilation, lighting, and sanitation facilities.

Sustainable housing in India is not only environmentally responsible, but it also provides economic benefits such as reduced energy costs, increased property value, and improved health and well-being of its residents.

2.9 Material That Can Be Used In Prefabricated Housing

Using panels, steel frames, composite wood materials, concrete, hybrid systems, shipping containers, agricultural, landscaping, red-list, recycled and reused materials can speed up on-site construction times and reduce overall construction time. This can lead to financial benefits. However, challenges include finding trained labor and coordinating new systems with traditional on-site construction practices**.**

2.9.1 Structurally Insulated Panels (SIPs)

Structurally Insulated Panels (SIPs) are a type of prefabricated building material with superior insulation, air tightness, and structural strength. Made from OSB or plywood with an insulating foam core, they offer easy assembly, energy efficiency, and durability for a variety of building types. SIPs have a higher R-value than stick-built construction, which can lead to long-term cost savings. While slightly higher in upfront cost, the benefits make it a worthwhile investment.

2.9.2 Wood

Using wood for prefabricated housing offers sustainability, quick on-site assembly, and potential cost savings.

- Although wood's insulation value is comparable to traditional methods, thicker insulation panels can be made.
- Wood can be locally sourced and reduce labor expenses while also being energy-efficient. Overall, wood is a viable option for prefabricated housing.

2.9.3 Composite Wood material

Composite wood materials, such as OSB and plywood, are popular for prefabricated housing due to their strength, durability, and ease of assembly.

- They offer similar insulation value to traditional construction and can be manufactured with thicker insulation for higher R-values. Composite wood materials can be cost-effective due to their prefabrication and reduced on-site labor costs, leading to faster project completion and reduced expenses.
- They also offer energy efficiency and reduced thermal bridging. Overall, composite wood materials are a durable, efficient, and cost-effective option for prefabricated housing.

2.9.4 Steel

Steel is a durable and easy-to-assemble material that is popular for prefabricated housing.

- While it may have a lower insulation value than traditional methods, steel panels can be insulated with a variety of materials.
- Using steel can offer cost savings through reduced labor expenses and construction time. Steel is also highly durable, requires minimal maintenance, and can withstand severe weather conditions. Overall, using steel for prefabricated housing can offer several benefits in terms of durability, efficiency, and cost-effectiveness.

2.9.5 Concrete

Concrete is popular for prefabricated housing due to its strength, durability, and fire resistance.

- Although it may have a lower R-value than traditional stick-built construction, concrete panels can be insulated to achieve similar values.
- Concrete offers cost savings through prefabrication, reduced on-site labour costs, and minimal maintenance expenses

2.9.6 Agricultural and landscaping materials

Agricultural and landscaping materials like straw bales, hempcrete, and green roofs can provide sustainable and environmentally-friendly options for prefabricated housing.

- They offer varying R-values but often provide superior insulation compared to traditional methods.
- These materials can be cost-effective and offer long-term savings through energy efficiency and reduced maintenance costs. They also provide aesthetic and functional benefits, improved air quality, and stormwater management. Using these materials can offer a sustainable and cost-effective alternative to traditional building materials.

2.9.7 Recycled and Reused Materials

Recycled and reused materials, like reclaimed wood and shipping containers, offer sustainable and cost-effective options for prefabricated housing.

- They can provide comparable or superior insulation and potential long-term cost savings through increased energy efficiency and reduced maintenance costs.
- Using these materials also offers environmental benefits like reduced waste and carbon emissions and unique aesthetic and functional benefits like improved acoustic properties.

2.9.8 Shipping containers

Shipping containers can be repurposed for prefabricated housing, offering a sustainable and cost-effective option.

- The insulation value varies based on construction methods and insulation materials used but can be comparable to traditional methods.
- Costs can vary depending on factors like container size, modifications, and location, but can be lower than traditional construction.

2.10 Cost Analysis Case Study

2.10.1 Ministry Of Railways

This cost analysis is based on a report made by the Research Designs & Standards Organisation, Lucknow for the MINISTRY OF RAILWAYS in 2014.

The unit cost of construction per square meter has been calculated below after excluding the cost of excavation & construction of foundations, floorings, plumbing and sanitary fitting. The cost of electrical work has also been excluded.

The unit cost of prefab construction per square meter consists of

- Design and detailed drawings for steel framework.
- External and internal wall and roof truss steel structure.
- Roof sheeting of coated galvalume sheet.
- Roof and wall insulation including external and internal wall cladding.

- False ceiling
- Fabrication, Transportation from shop to site and Erection of the same

Description of the structure	cost per Sq.m. of conventional method	Cost of prefab construction per Sq.m.	% increase/ decrease with respect to a conventional method
Two room accommodation with basic amenities	Rs.5733/- per sq.m.	Rs.17384/- per sq.m	(+) 203%

Table 1 - Cost analysis made for ministry of railways, 2014

2.10.2 Maharashtra state police housing

This cost analysis is of Maharashtra state police housing and welfare corp. ltd.
The total plot area for this housing is 25863 sq.m with 132 flats.

Sr. No.	Components	Conventi-onal Cost in Rs	Precast Cost in Rs	Differences in Cost (Rs)
1.	Column	192420	165096	27324
2.	Beam	225385	190602	34783
3.	Lintel	11632	11133	499
4.	Slab	356044	281995	74049
5.	Lintel with Chajja	17316	16682	634
6.	Stair case	25416	19880	5536
	Total	**828213**	**685388**	**142825**

Table 2 - Cost analaysis made for Maharashtra state police housing

This demonstrates that prefabricated housing is more affordable when many units are produced, but more expensive when fewer units are produced.

Chapter-3

3.1 Research Design

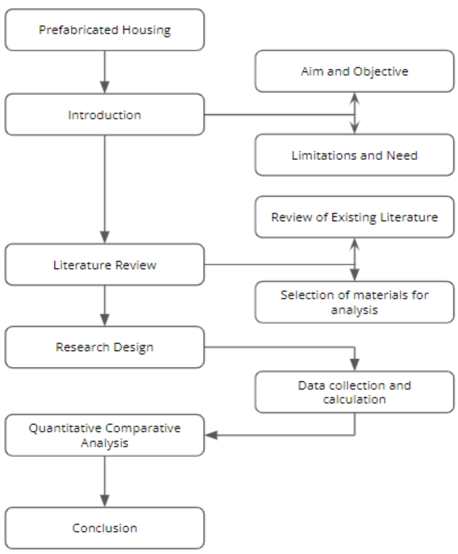

Figure 3 Methodology Flow Chart

3.2 Review of the Existing Literature

The methodology for this study was developed based on a comprehensive review of the existing literature on the topic. The literature review aimed to identify relevant theories, concepts, and methodologies used in previous studies related to Prefabricated housing. The review encompassed a range of scholarly articles, books, and reports, sourced from reputable databases and academic libraries.
The findings from the literature review guided the selection of appropriate materials for this study. It also helped in finding all the databases for the calculation for the analysis.

3.2 Material Selection and Data Collection.

The material was selected on the basis of its sustainability and affordability. The data for sustainability analysis was collected from environmental declaration Reports published by the manufacturers and " India Construction Materials Database of Embodied Energy and Global Warming Potential, METHODOLOGY REPORT, 2017 "The data for cost analysis was collected by Contacting various Vendors.

3.3 Quantitative Comparative Analysis

The Methodology employed for this study consists of Quantitative Comparative Analysis.
For this method, quantitative comparative analysis to compare the embodied energy, embodied carbon, and cost of Conventional and prefabricated construction systems has been used. This methodology involves collecting quantitative data related to these metrics for both systems, analyzing and interpreting the data, and drawing conclusions based on numerical comparisons.

3.4 Conclusion

The conclusion was given on the basis of analysis and Review of existing Literature.

Chapter-4

4.1 Analysis Of the Conventional Construction

For this study, we will use an EWS housing made up of bricks and RCC columns. The carpet area of this house is **25 sqm.** The height from floor to ceiling is 3 meters.

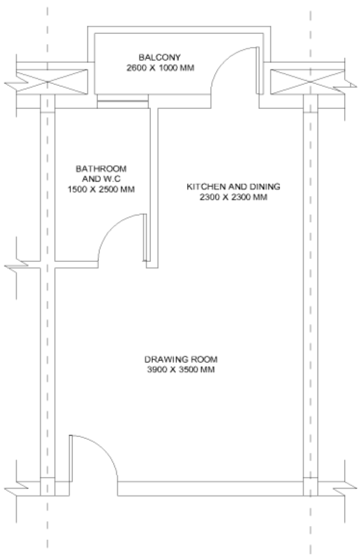

Figure 4- Plan of EWS housing made from Conventional methods

Component	Specification
External wall	230 mm thick brick wall
Internal wall	115mm thick brick wall
Roof	115 mm thick flat reinforced cement concrete (RCC) roof (concrete mix - 1:1:2) (the diameter of steel to be 10mm and spacing 150 cm) (M 25)
Columns	230 x 300mm RCC columns
Flooring	40 mm thick plain cement concrete (PCC) (concrete mix - 1:2:4) (M 15)

Table 3- Specification of the Ews housing made of conventional method

4.1.1 Embodied Energy Of the Conventional Construction System

4.1.1.1Embodied Energy of construction materials

Item	Embodied energy (MJ/Kg)
Cement	5.9-7.8 (avg 6.85)
Fine aggregate	0.1-0.2 (avg 0.15)
Coarse aggregate	0.4
Reinforcement Steel	28.2-42 (avg 35.1)
Burnt clay bricks	1.8

Table 4- Embodied energy of different materials of conventional method

Source- India Construction Materials Database of Embodied Energy and Global Warming Potential, METHODOLOGY REPORT, 2017

4.1.1.2 Table of Embodied Energy of Conventional Construction System

Material	THK. (M)	Area Density (KG/ m2)	DENSITY (KG/ M3)	EE (MJ/ KG)	Running Meter	TOTAL AREA (M2)	TOTAL AMOUNT USED (KG)	TOTAL EE OF MATERIAL (MJ)
Walls								
Assembly 1								
Brick Walls	0.115	-	1,760	6.5	-	34.8	7043.52	45782.88
Cement Based	0.01	-	2200	4.8	-	34.8	765.6	3674.88

Plaster								
Assembly 2								
Cement Based Plaster	0.01	-	2200	4.8	-	23.4	514.8	2471.04
Brick walls	0.23	-	1,760	6.5	-	23.4	9472.32	61570.08
Cement Based Plaster	0.01	-	2200	4.8	-	23.4	514.8	2471.04
Assembly 3								
Cement Based Plaster	0.01	-	2200	4.8	-	12.6	277.2	1330.56
Brick walls	0.115	-	1,760	6.5	-	12.6	2550.24	16576.56
Cement Based Plaster	0.01	-	2200	4.8	-	12.6	277.2	1330.56
Flooring								
Concrete mix (M15)	0.04	-	2,400	0.7	-	26.4	2534.4	1774.08
Glazed Ceramic tiles	0.011	17	-	0.67	-	26.4	448.8	300.696
Roofing								
Concrete mix (M25)	0.115	-	2500	0.74	-	26.4	7590	5616.6
Rebar Steel	0.006	-	0.2 kg/M	30	158	-	31.6	948
Column								
Concrete (M20)	0.115	-	2500	0.74	-	3.6	1035	765.9
Rebar Steel	0.012	-	0.6 Kg/M	30	24	-	14.4	432
Beams								
Assembly 1								
Concrete (M20)	0.115	-	2500	0.74	-	2.76	793.5	587.19
Rebar Steel	0.012	-	0.6 Kg/M	30	32	-	4	120
Assembly 2								
Concrete (M20)	0.23	-	2500	0.74	-	2.76	1587	1174.38
Rebar Steel	0.012	-	0.6 Kg/M	30	32	-	4	120
							Total	147046.446

Table 5- Total Embodied energy Calculation of conventional method

Embodied Energy of EWS house made of Conventional methods is 147046.4 MJ

4.1.2 Embodied Carbon Of the base case

4.1.2.1 Embodied Carbon of construction materials

Item	Embodied carbon (kgco2eqJ/Kg)
Cement MIx (1:2:4) (M 15)	0.21
Cement Mix (1:1:2) (M25)	0.29
Reinforcement Steel	1.265
Burnt clay bricks	0.6

Table 6- Embodied Carbon of different materials of conventional method

Source - Environmental Product Declaration report

4.1.2.1 Table of Embodied Carbon of Conventional construction system

Material	THK. (M)	Area Density (KG/ m2)	DENSITY (KG/ M3)	EC (kg CO2 eq/ KG)	Running Meter	TOTAL AREA (M2)	TOTAL AMOUNT USED (KG)	TOTAL EE OF MATERIAL (kg CO2 eq)
Walls								
Assembly 1								
Brick Walls	0.115	-	1,760	0.59	-	34.8	7043.52	4155.6768
Cement Based Plaster	0.01	-	2200	0.44	-	34.8	765.6	336.864
Assembly 2								
Cement Based Plaster	0.01	-	2200	0.44	-	23.4	514.8	226.512
Brick walls	0.23	-	1,760	0.59	-	23.4	9472.32	5588.6688
Cement Based Plaster	0.01	-	2200	0.44	-	23.4	514.8	226.512
Assembly 3								
Cement Based Plaster	0.01	-	2200	0.44	-	12.6	277.2	121.968
Brick walls	0.115	-	1,760	0.59	-	12.6	2550.24	1504.6416
Cement Based Plaster	0.01	-	2200	0.44	-	12.6	277.2	121.968
Flooring								

Concrete mix (M15)	0.04	-	2,400	0.1	-	26.4	2534.4	253.44
Glazed Ceramic tiles	0.011	17	-	0.67	-	26.4	448.8	300.696
Roofing								
Concrete mix (M25)	0.115	-	2500	0.1	-	26.4	7590	759
Rebar Steel	0.006	-	0.2 kg/M	2.6	158	-	31.6	82.16
Column								
Concrete (M20)	0.115	-	2500	0.1	-	3.6	1035	103.5
Rebar Steel	0.012	-	0.6 Kg/M	2.6	24	-	14.4	37.44
Beams								
Assembly 1								
Concrete (M20)	0.115	-	2500	0.1	-	2.76	793.5	79.35
Rebar Steel	0.012	-	0.6 Kg/M	2.6	32	-	4	10.4
Assembly 2								
Concrete (M20)	0.23	-	2500	0.1	-	2.76	1587	158.7
Rebar Steel	0.012	-	0.6 Kg/M	2.6	32	-	4	10.4
							Total	14077.8972

Table 7- Total Embodied Carbon calculation of conventional method

Embodied Carbon of EWS Flat made of Conventional methods is 14077.9 kg CO2 eq

4.1.3 Total Cost of Conventional Construction System

4.1.3.1 Table of Total Cost Calculation of In Situ Construction System

Material	**THK. (M)**	**Running Meter**	**Total Weight**	**Cost/ kg**	**Cost / m2**	**Cost / m3**	**Quantity / m2**	**TOTAL AREA (M2)**	**Total Volume (m3)**	**Total Cost**
Walls										
Assembly 1										
Brick Walls	0.115	-	-		420	-	60	34.8	-	14616
Cement Based Plaster	0.01	-	-		38.25	-	-	34.8	-	1331.1
Assembly 2										
Cement Based Plaster	0.01	-	-		38.25	-		23.4	-	895.05
Brick walls	0.23	-	-		840	-	120	23.4	-	19656

Cement Based Plaster	0.01	-	-		38.25	-		23.4	-	895.05
Assembly 3										
Cement Based Plaster	0.01	-	-		38.25	-		12.6	-	481.95
Brick walls	0.115	-	-		420	-	60	12.6	-	5292
Cement Based Plaster	0.01	-	-		38.25	-		12.6	-	481.95
Flooring										
Concrete mix (M15)	0.04	-	-		-	7,307	-	26.4	1.056	7716.192
Glazed Ceramic tiles	0.011	-	-		250	-	-	26.4	-	6600
Roofing										
Concrete mix (M25)	0.115	-	-		-	9204	-	26.4	3.036	27943.344
Rebar Steel	0.008	158	31.6	73.13				-		2310.908
Column										
Concrete (M20)	0.115	-	-		-	8046	-	3.6	0.414	3331.044
Rebar Steel	0.012	24	14.4	70.47				-		1014.768
Beams										
Assembly 1										
Concrete (M20)	0.115	-			-	8046	-	2.76	0.3174	2553.8004
Rebar Steel	0.012	32	4	70.47				-		281.88
Assembly 2										
Concrete (M20)	0.23	-			-	8046	-	2.76	0.6348	5107.6008
Rebar Steel	0.012	32	4	70.47				-		281.88
									Total cost	100790

Table 8- Total Cost Calculation of conventional method

The total cost of EWS units made of Conventional methods is Rs 1,00,790

4.2 Analysis Of Prefabricated Housing

For this study, we will take an EWS housing made up of a steel structure. The carpet area of this house is **25 sqm.** The height from floor to ceiling is 3 meters.

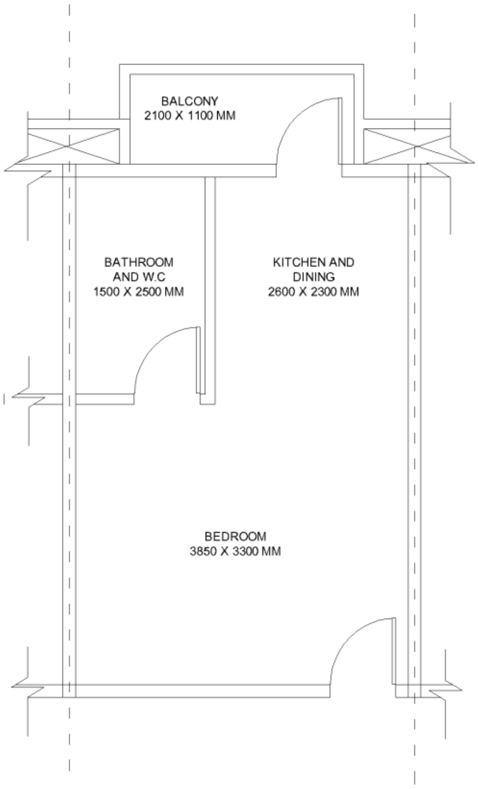

Figure 5- Plan of EWS housing made from Prefabricated methods

Component	**Specification**
Structure	Steel Section (59% Recycled) (100x100) Steel Sections (59% Recycled) (150X150)
Wall	AAC panels 150 mm
Flooring	Fiber cement board 18mm, Glazed Ceramic Tiles
Roofing	Puff Panels 60mm

Table 9- Specification of the Ews housing made of prefabricated method

4.2.1 Embodied Energy Of Prefabricated Housing

4.2.1.1 Embodied Energy of construction materials

Item	**Embodied energy (MJ/Kg)**
Steel Structure (59% Recycled)	20.1

Ferrocement Panel (wall)	2.3
ACC Panels	3.7
Glazed ceramic Tiles	7.8
Fibre Cement Board	10.40

Table 10- Embodied energy of different materials of prefabricated method

Source- India Construction Materials Database of Embodied Energy and Global Warming Potential, METHODOLOGY REPORT, 2017

4.2.1.2 Table of Embodied Energy of Conventional Construction System

Material	THK. (M)	Area Density (KG/ m2)	DENSITY (KG/ M3)	EE (MJ/ KG)	Running Meter	TOTAL AREA (M2)	TOTAL AMOUNT USED (KG)	TOTAL EE OF MATERIAL (MJ)
Walls								
Assembly 1								
AAC Panels	0.1	-	500	3.7	-	34.8	1740	6438
Assembly 2								
AAC Panels	0.15	-	500	3.7	-	22.8	1710	6327
Assembly 3								
AAC Panels	0.075	-	500	3.7	-	12.6	472.5	1748.25
Flooring								
Steel corrugated Sheets	0.001	-	7,750	32	-	25	193.75	4843
Fibre Cement Board	0.018	23	1,200	10.4	-	25	540	5616
Glazed Ceramic tiles	0.011	17	-	7.8	-	24.4	414.8	3235.44
Roofing								
Puff Panels	0.03	3	40	102	-	25	75	7650
Structure								
Steel Structure (59% Recycled) 100x100	-	-	6 kg / M	20.1	7.6	-	45.6	916.56
Steel Structure (59% Recycled)	-	-	34 Kg/M	20.1	19.4	-	659	13245.9

150x150								
							Total	50020.15

Table 11- Total Embodied energy Calculation of prefabricated method
Embodied Energy of EWS house made of Conventional methods is 50020.14 MJ

4.2.2 Embodied Carbon Of Prefabricated Housing
4.2.2.1 Embodied Carbon of construction materials

Item	**Embodied Carbon (kgCO2e/kg)**
Steel Structure (59% Recycled)	0.75
Ferrocement Panel (wall)	0.29
ACC Panels	0.5
Glazed ceramic Tiles	0.67
Fibre Cement Board	1.09

Table 12- Embodied energy of different materials of prefabricated method
Source- India Construction Materials Database of Embodied Energy and Global Warming Potential, METHODOLOGY REPORT , 2017

4.2.2.2 Table of Embodied Carbon of Prefabricated Construction System

Material	**THK. (M)**	**Area Density (KG/ m2)**	**DENSITY (KG/ M3)**	**EC (kgCO2e/ KG)**	**Running Meter**	**TOTAL AREA (M2)**	**TOTAL AMOUNT USED (KG)**	**TOTAL EC OF MATERIAL (KG CO2.EQ)**
Walls								
Assembly 1								
AAC Panels	0.1	-	500	0.5	-	34.8	1740	870
Assembly 2								
AAC Panels	0.15	-	500	0.5	-	22.8	1710	855
Assembly 3								
AAC Panels	0.075	-	500	0.5	-	12.6	472.5	236.25
Flooring								
Steel corrugated Sheets	0.001	-	7,750	2.7	-	25	193.75	523.125
Fibre Cement	0.018	23	1,200	1.09	-	25	540	588.6

Board								
Glazed Ceramic tiles	0.011	17	-	0.67	-	24.4	414.8	277.916
Roofing								
Puff Panels	0.03	3	40	102	-	25	75	7650
Structure								
Steel Structure (59% Recycled) 100x100	-	-	6 kg / M	0.75	7.6	-	45.6	34.2
Steel Structure (59% Recycled) 150x150	-	-	34 Kg/M	0.75	19.4	-	659	494.25
							Total	11529.341

Table 13- Embodied energy Calculation of prefabricated method

Embodied Carbon of EWS Flat made of Conventional methods is 11529.341 kg CO2 eq

4.2.3 Total Cost Of Prefabricated Housing

Material	THK. (M)	Area Density (KG/ m2)	DENSITY (KG/ M3)	Cost per sq m	Cost per kg	Running Meter	TOTAL AREA (M2)	TOTAL AMOUNT USED (KG)	Total Cost
Walls									
Assembly 1									
AAC Panels	0.1	-	500	1200	-	-	34.8	1740	41760
Assembly 2									
AAC Panels	0.15	-	500	1200	-	-	22.8	1710	27360
Assembly 3									
AAC Panels	0.075	-	500	1200	-	-	12.6	472.5	15120
Flooring									
Steel Corrugated sheets	0.001	-	-	665	-	-	25	-	16625
Fibre Cement Board	0.018	23	1,200	1200	-	-	25	540	30000
Glazed Ceramic tiles	0.011	17	-	236	-	-	24.4	414.8	5758.4
Roofing									
Puff Panels	0.03	3	40	1350	-	-	25	75	33750

Structure									
Steel Structure (59% Recycled) 100x100	-	-	6 kg / M	-	57	7.6	-	45.6	2599.2
Steel Structure (59% Recycled) 150x150	-	-	34 Kg/M	-	60	19.4	-	659	39540
								Total	212512.6

Table 14- Total cost Calculation of prefabricated method

The total cost of the proposed case turns out to be ₹212512.6 per functional unit.

Chapter-5

5.1 Analysis And Discussion

Analysis	**Conventional Construction**	**Prefabricated Construction**
Embodied Energy (MJ)	147046.4	50020.14
Embodied Carbon (kgCO2 eq)	13655.775	11529.341
Cost per Functional Unit (₹)	100790.5	212512.6

Table 15- Analysis

The analysis compares two construction methods: In Situ construction and Prefabricated construction. The parameters evaluated are Embodied Energy, Embodied Carbon, and Cost per Functional Unit.

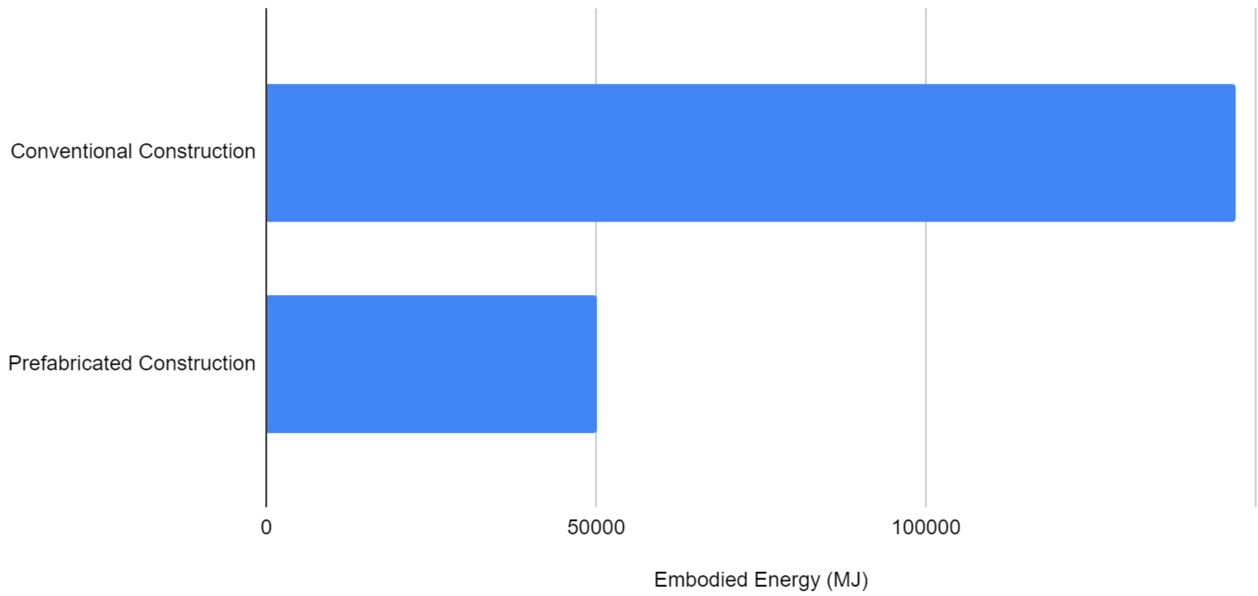

Figure 6- Analysis of Embodied Energy

Embodied Energy refers to the total energy consumed throughout the lifecycle of a construction method, including extraction, transportation and manufacturing. In this analysis, the In Situ construction method has an embodied energy of 147,046.4 MJ, while the Prefabricated construction method has a lower embodied energy of 50,020.14 MJ. This indicates that the Prefabricated construction method is more energy-efficient compared to In Situ construction.

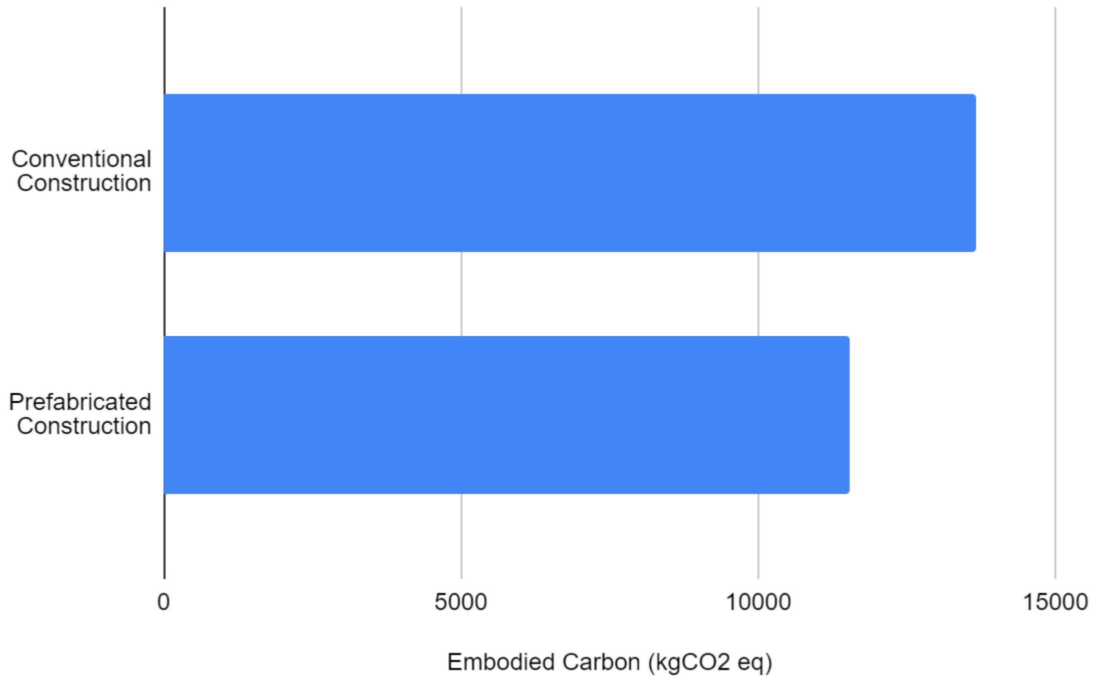

Figure 7- Analysis of Embodied Carbon

Embodied Carbon represents the total amount of carbon dioxide equivalent (CO_2 eq) emissions associated with a construction method. The In Situ construction method has an embodied carbon of 13,655.775 kgCO_2 eq, while the Prefabricated construction method has a slightly lower embodied carbon of 11,529.341 kgCO_2 eq. This suggests that the Prefabricated construction method has a lower carbon footprint compared to In Situ construction. 2,126 kgCO_2 eq equivalent to CO_2 released from 893 litres of Petrol.

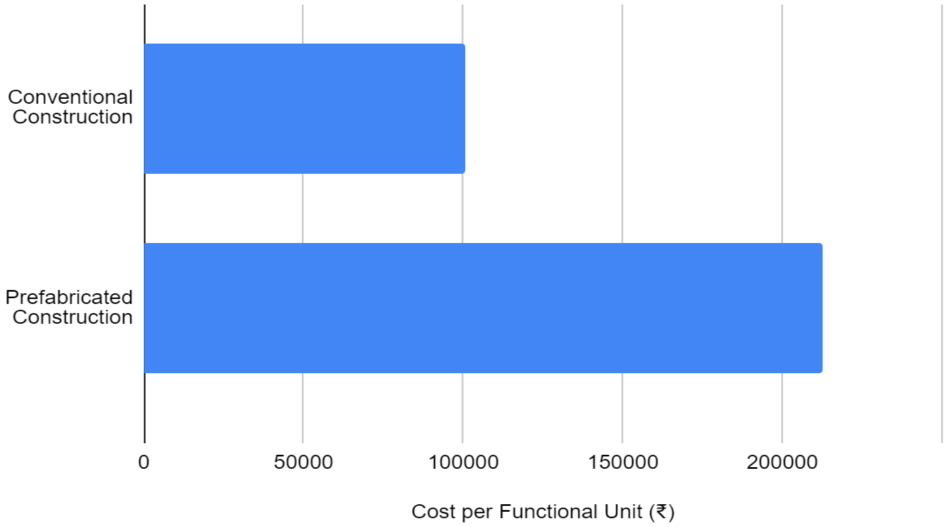

Figure 8- Analysis of Cost per Functional unit

Cost per Functional Unit reflects the cost required to achieve a specific functional unit. In this analysis, the In Situ construction method has a cost per functional unit of ₹100,790.5, whereas the Prefabricated construction method has a higher cost per functional unit of ₹212,512.6. This indicates that Prefabricated construction is relatively more expensive compared to In Situ construction

Chapter-6

6.1 Conclusion

The findings of the analysis highlight several important aspects regarding the comparison between conventional construction and prefabricated construction.

Firstly, in terms of embodied energy, prefabricated construction demonstrates a clear advantage over conventional construction. The analysis reveals a substantial reduction of 97,026.26 MJ in embodied energy for prefabricated construction compared to conventional construction. This reduction indicates a more environmentally sustainable approach, as less energy is consumed during the manufacturing and assembly processes of prefabricated components.

Similarly, in terms of embodied carbon emissions, prefabricated construction outperforms conventional construction. The analysis shows a reduction of 2,126.434 kg CO2 eq in embodied carbon for prefabricated construction. This reduction indicates a lower carbon footprint associated with prefabricated components, contributing to mitigating climate change impacts.

However, it is important to acknowledge that the cost per functional unit for prefabricated construction is significantly higher compared to conventional construction. The analysis reveals a cost difference of 1,11,731.1 ₹ per functional unit, indicating a higher initial investment required for prefabricated construction.

While this cost disparity raises concerns about the short-term affordability of prefabricated construction, it is crucial to consider the long-term cost implications. Several factors can influence the long-term financial feasibility of prefabricated construction, such as maintenance and operational expenses, energy efficiency, durability, and life cycle costs. It is possible that prefabricated construction may offer cost savings over time due to reduced maintenance needs, improved energy efficiency, and longer lifespan compared to conventional construction.

In conclusion, while prefabricated construction offers advantages in terms of embodied energy and carbon emissions, the higher initial cost per functional unit raises concerns about short-term affordability. However, to fully assess the financial feasibility, it is necessary to consider long-term cost implications, including maintenance, energy efficiency, and life cycle costs. Further research is needed to provide a comprehensive understanding of the economic benefits of prefabricated construction and enable informed decision-making in the construction industry.

6.2 Future Scope

To fully evaluate the cost-effectiveness of prefabricated construction in the long term, it is recommended to consider factors such as maintenance and operational expenses, energy efficiency, durability, and life cycle costs. These aspects can play a significant role in determining the overall economic benefits of prefabricated construction.

References

1. BC Housing (Ed.). (2014). Modular and Prefabricated Housing: Literature Scan of Ideas, Innovations, and Considerations to Improve Affordability, Efficiency, and Quality. Modular and Prefabricated Housing: Literature Scan of Ideas, Innovations, and Considerations to Improve Affordability, Efficiency, and Quality
2. Deepak Bansal, V. K. Minocha, & Arvinder Kaur. (2021). Reduction of Embodied Energy and Construction Cost of Affordable Houses through Efficient Architectural Design: A Case Study in Indian Scenario. Reduction of Embodied Energy and Construction Cost of Affordable Houses through Efficient Architectural Design: A Case Study in Indian Scenario
3. Hammond, G. (2010). *The Inventory of Carbon and Energy (ICE)*. Embodied Carbon - The Inventory of Carbon and Energy (ICE)
4. International Finance Corporation. (2017). India Construction Materials Database of Embodied Energy and Global Warming Potential METHODOLOGY REPORT. India Construction Materials Database of Embodied Energy and Global Warming Potential METHODOLOGY REPORT | EDGE Buildings
5. jsw group. (2022). Cold Rolled Close Annealed Coil (STEEL) Environmental Product Declaration. Cold Rolled Closed Annealed Coil (STEEL) - Environmental Product Declaration
6. JSW Group. (2022). Environmental Product Declaration of Average of Finished Flat Products (Steel). https://api.environdec.com/api/v1/EPDLibrary/Files/3ddb7ee4-23e1-46ef-8729-08d9d73a4e22/Data
7. Lakhi M. Chavan, & Prof. D.B.Desai. (2017). Analyze time cost required for conventional and prefabricated building components. Analyze time-cost required for conventional and prefabricated building components
8. Narayanamurthy, S. (2009). Prefabrication in Developing Countries: a case study of India. Prefabrication in Developing Countries: A Case Study of India
9. Nur Arzwin Mohamed Aris, Mohamad Syazli Fathi, Aizul Harun, & Zainai Bin Mohamed. (2019). ArticlePDF Available Towards A Sustainable Supply of Affordable Housing with Prefabrication Technology: An Overview. Towards A Sustainable Supply of Affordable Housing with Prefabrication Technology : An Overview
10. Research Designs & Standards Organisation, Lucknow (Ed.). (2014). Report on Prefabricated Buildings. Report on Prefabricated Buildings
11. Visaka Industries Limited. (2022). Environmental Product Declaration for Vnext- Fiber Cement Boards. https://api.environdec.com/api/v1/EPDLibrary/Files/d5f28aa4-5377-4354-ad06-08da599e304a/Data
12. Visaka Industries Limited. (2022). Environmental Product Declaration for: Vnext Panels. https://api.environdec.com/api/v1/EPDLibrary/Files/29eb0051-c3a6-4219-adf9-08da599e304a/Data

Annexure

Name	Title	Year	Aim	Findings

Shilpa Narayanamurthy	Prefabrication in Developing Countries: a case study of India	2009	The aim of this study is to examine the advantages and disadvantages of prefabrication adoption in developing countries, with a focus on India. The study will also explore the potential for prefabrication to create a bland, monotonous landscape and its impact on fostering personal and collaborative skills, culture, tradition, and community building	it discusses the challenges and ethical dilemmas related to the transfer of prefabrication technology to developing countries and emphasizes the need for architects to be aware of the potential impact of their decisions on the cultural and social aspects of these countries.
BC Housing	Modular and Prefabricated Housing: Literature Scan of Ideas, Innovations, and Considerations to Improve Affordability, Efficiency, and Quality	2014	The aim of the study is to identify ideas, practices, and innovations that help maximize the potential benefits of prefab and modular construction for affordable housing, as well as to examine their potential use as emergency lodging. The study also aims to address challenges and considerations with each idea, practice, and innovation, and to explore other construction forms that could be considered as part of the modular construction process or finished product.	The findings of this study suggest that the modular and prefabricated building market is growing rapidly and has the potential to provide benefits such as time and cost savings, sustainability, and performance. The study found examples of modular or prefabricated residential construction that provide learning for the affordable housing sector and beyond. The report suggests that appropriate planning and consideration from the conceptual phase can maximize the potential benefits of modular and prefabricated construction.
Nur Arzwin Mohamed Aris, Mohamad Syazli Fathi , Aizul Nahar Harun , Zainai Mohamed	Towards A Sustainable Supply of Affordable Housing with Prefabrication Technology : An Overview	2019	The aim of the literature study is to explore the issues related to the utilization of prefabrication technology in affordable housing construction in Malaysia and to identify strategies that can be adopted by stakeholders to ensure sustainable supply of affordable houses. The study analyzes 60 papers published	The findings of this study suggest that the use of prefabrication technology in the construction of affordable housing in developing countries like Malaysia can be a sustainable solution to the increasing demand for housing due to population growth and urbanization. The adoption of Industrialized Building System

			between 2003 and 2017 and identifies five main themes of prefabrication technology issues: assemble, workmanship, financial, logistic, and project information system. The study suggests that a more holistic approach is needed, driven by three main components (people, process, and technology) to address these issues and ensure sustainable supply of affordable housing through prefabrication technology.	(IBS) by developers can reduce overall construction costs and provide a sustainable supply of affordable housing. However, there are several issues related to prefabrication technology, such as assemble, workmanship, financial, logistic, and project information system issues, that need to be addressed by stakeholders. The study also suggests that a more holistic approach is needed, with a focus on people, process, and technology. The business model of prefabrication technology for affordable housing supply should be further explored through case studies to improve the overall effectiveness of the process. Finally, the study recommends that the research should be extended to densely populated areas, such as the state of Selangor in Malaysia, where there is a high demand for affordable housing.
Deepak Bansal , V. K. Minocha, Arvinder Kaur, Vaidehi A. Dakwale and R. V. Ralegaonkar	Reduction of Embodied Energy and Construction Cost of Affordable Houses through Efficient Architectural Design: A Case Study in Indian Scenario	2021	The aim of the study was to analyze the impact of architectural design on the embodied energy and cost of construction of Indian affordable housing units (IAHUs) and to determine the relationship between the built-up-to-carpet area ratio and sustainability of IAHUs.	This study analyzed 30 clusters of Indian affordable housing units (IAHUs) of similar typology and different architectural designs to understand how the built-up-to-carpet area ratio affects the embodied energy and construction cost of IAHUs. The study found that an efficient architectural design that minimizes the ratio of the built-up and carpet area can simultaneously reduce the cost of construction and embodied

				energy. The study concludes that the built-up-to-carpet area ratio is an important indicator of sustainability in IAHUs and that efficient architectural designs are essential for sustainable and affordable housing.
Research Designs & Standards Organisation, Lucknow	Report on Prefabricated Buildings	2014	The aim of the report is to provide basic concepts of prefabricated building and market analysis with a focus on Indian Railway establishment. It also covers the advantages, disadvantages, material specifications, and cost benefits of prefabricated building concepts. The report is prepared as per the instruction of Railway Board.	
Lakhi M. Chavan1, Prof. D.B.Desai2	Analyze time-cost required for conventional and prefabricated building components	2017	The aim of the project is to analyze the advantages and disadvantages of prefabricated building techniques as compared to traditional construction methods. The project aims to focus on the various benefits of prefabrication such as availability of materials, labor, and technical skills, self-supporting components, elimination of shuttering and scaffolding, and reduction in time and cost. The project also aims to compare the repetitive use of shuttering in traditional construction to the cost-effective and repetitive use of molds in prefabricated housing systems.	The findings of this study suggest that utilizing precast building components can result in cost savings of up to 17.24% and reduce project duration by up to 26%. The use of precast methodology can help achieve economy and fast-track construction in the construction industry. The study also found that precast construction requires less time compared to conventional construction and results in better quality. Additionally, the study recommends developing selection criteria for choosing the appropriate methodology to optimize cost and time for specific projects based on existing site conditions.