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The Role of Modular Construction in Achieving Sustainable Building Goals

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ABSTRACT

The Research is comprised of using modular construction to achieve Sustainability. The global trendis experiencing the importance of modular construction. Modular construction can reduce the time it takes to design and engineer a building, lower costs and increase construction efficiency and productivity. Modular building construction is cost-efficient, safe, durable, flexible and eco-friendly. The trends experience an accelerated bloomof modular construction technology in India.

By learning from the experience of most construction front nations development of concrete modules according to site requirements has increased. As the Research's findings demonstrate, new modular construction technologies are promising for providing sustainable,convenient, and environmentally friendly housing to the general public. The dissertation describes the process and sustainability of modular construction. So that the need for housing or any other construction requirement can be made possible on short notice.

Keywords: Modular Construction, Sustainability, Cost-Efficiency, Durability, Eco-Friendly.

1. *Introduction*

Modular construction techniques are experiencing rapid growth due to their significant advantages over traditional construction methods. This approach is particularly cost-effective and time-saving, making it ideal for commercial and high-rise buildings. In modular construction, 3D modules and prefabricated elements are manufactured in a factory under controlled conditions, ensuring high quality and precision. These modules are then transported to the construction site, where they are assembled by skilled labourers and cranes. One of the

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primary benefits of modular construction is its contribution to sustainability. This technique offers numerous social, economic, and environmental advantages. For instance, the controlled factory environment minimizes waste and pollution, while the efficient use of materials reduces overall costs. The speed of construction also decreases the time buildings are under construction, which lessens the environmental impact. Furthermore, modular construction allows for the integration of services such as plumbing and electrical systems directly into the modules during the factory phase. This integration not only streamlines the on-site assembly process but also enhances the overall quality and reliability of the building systems. The repetitive use of standardized modules ensures cost-effectiveness and consistency across projects.

Figure 1. Modular construction

2. ***Literature Review***

In the 1830s, John Manning, a London carpenter, built a prefabricated house for his son, who was relocating to Australia from England. He made the prefabricated house in pieces and then shipped it into the “Land Down Under” so that it became easy to assemble.

In the 1840s, housing needs increased during the California Gold Rush. In that situation, Modularconstruction has found its way into the housing markets.

In 1851, the “Crystal Palace” was built for Britain's Great Exhibition, and it remained as famous example of early modular construction of that time. It was designed in less than two weeks, and it used light and cheap materials such as iron, wood, glass, etc. It was built in only a few months. After some time, the castle was dismantled, moved and rebuilt in another location.

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In 1900's, a builder in Chicago, named Augustine Taylor, invented the balloon-frame method, facilitating walls to be built off the site. For speedy assembly, it was then transported to the intended construction site.

In the Rise of Catalog houses between 1908 and 1940, Sears Roebuck and Company sold more than 5,00,000 prefabricated houses through their catalogue, straight to the customers. At that time,these prefabricated houses cost less than two-thirds of the precisely built houses, and these prefabricated houses are still in existence in the United States.

World War II After WWII demand for houses increased. As the soldiers returned to their homes after the war. At that time the United States experienced great demand for housing. At that time speedyconstruction was needed to accommodate the expanding families of soldiers. With the help ofmodular construction, needs were fulfilled. As it is efficient, reduces costs and is quick to construct.

Because it is effective, low-cost, and easy to build. Modularization and prefabrication are preferred in today's world of construction for buildings such as apartments, offices, hotels, hospitals, and schools in every major city.

The percentage of prefabricated structures (modular construction) per industry is as follows:

- 49% of medical centers
- 42% of student housing buildings and college buildings
- Moreover, industrial structures account for 42% of all structures.

In comparison to traditional construction methods, Modular construction is a faster approach that reduces the likelihood of going over budget and beyond reach.

Modular construction helps in avoiding a lot of snares and more time consumption that can be found in conventional construction methods by keeping the offsite environment controlled. Modular construction can reduce the uncertainty of scheduling issues and labour the result of which means that there is less of a chance for a delay. This is partially dueto the shrinking workforce in the building industry. A company offering modular constructionwill also hire a team of full-time staff in the production centre to handle all necessary offsite construction and manufacturing of the modular units.

Modular construction can be more efficient and cost-effective with a consistent labour force. Throughout the years, by cutting 35% of businesses' schedules by a month, the potential of modular construction to impact building projects positively has been demonstrated.

Modular construction can:

- Reduce construction waste by 77%

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- Reduce the project's entire cost by 65%

Generally, construction projects on a larger scale can often take about one-fifth longer duration to complete than estimated time and can run up to four-fifths over budget than estimated. Modular building techniques and methods positively impact the budget of a construction project since the method is much faster than the traditional approaches.

Modular construction is gaining popularity worldwide, with more and more builders and developers recognizing its utility, productivity, and cost-effectiveness.

3. ***Different Types of Materials Used***

Modular Construction materials are:

• Wood

• Steel

• R.C.C

Modular building materials used for small prefabricated buildings are:

• Steel

• Wood

• Fiberglass

• Plastic

• Aluminum

4. ***Sustainable Material for Modular Construction***

➢ Concrete

Concrete is the most popular building material in the world because it is durable and strong, but precast concrete is the most environmentally friendly. Precast concrete is manufactured in a regulated environment. It is then transported to a site that has already been strengthened and completed to standards, removing the need for on-site concrete casting and shortening the installation time. This reduces the impact of precast concrete buildings on the surrounding environment. Also helps in producing less construction pollution, debris, noise and dust. Cement, coarse and fine aggregates, and steel can all be sourced locally, eliminating shipping waste and the total carbon footprint of precast concrete. Its units can be disassembled in an existing structure to be moved/reconfigured, and concrete can be crushed and reused as aggregate. The thermal resistance of standard concrete is usually 0.11 per inch of thickness. Precast concrete, with a thickness of 0.22 inch, will have twice the resistance. Builders can

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choose between lightweight and dense precast concrete when determining the degree of thermal insulation needed. Concrete can also be used as a fire shield. Precast concrete wall panels will withstand a fire for two to four hours. They stay intact even in hot chemical fires, are resistant to wind-blown debris and rain penetration, and provide storm and weather protection.

Precast concrete's light colour reflects more sunshine and heat than dark surfaces, minimizing the urban heat island effect while also decreasing air conditioning costs. It has the potential tosave millions of dollars in annual energy costs. These concrete structures can also obtain up to 23 LEED certification points in new construction.

- **Steel**

Steel is remarkably recyclable, as it helps builders and designers follow steel building codes and win several points for the Green Building Rating Program (LEED or the Living Building Challenge). Any steel product can be recycled and repurposed into something else. Almost allsteel products now contain at least 25% recycled material, with some products containing up to 100% recycled content. Because of its recyclability, many steel building materials are manufactured off-site, reducing construction and demolition waste. Before shipping to the construction site modules are pre-manufactured and are precisely fabricated according to project specification. Steel is a strong and flexible material. It is also green material. It has good quality such as it doesn't expand and contract in the presence of moisture. Steel is termite-resistant. It can be assembled and disassembled and can be relocated as per site requirements.

- **Crossed-laminated timber**

Crossed-laminated timber: CLT is a panel made up of solid wood in which layering of boards is done in alternate directions and is joined using structural adhesive. Carbon footprint is reduced in CLT as it contains alternative fibre and solid composition. Work environment for workers improved on-site as less noise, dust and wastage is produced. By using CLT components, prefabricated floors can be installed in a week. CLT is a renewable building material that decreases greenhouse gas emissions and reduces the amount of energy used to produce CLT panels.

5. ***Sustainability of Modular Construction***

- Energy efficiency
- Minimizing transportation

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- Minimizing pollution
- Efficient materials and resources use
- Health and well-being

6. ***Sustainable Aspects of Triple Bottom Line***

➢ **Social**

- Upliftment of the quality of life of each individual and society as a whole.
- Human needs satisfaction
- Enhancing social benefits
- Social and cultural aspects of society to be considered

➢ **Economic**

- Betterment of economic growth.
- Betterment of productivity growth
- Increasing real income
- Reducing health costs
- Reducing infrastructure costs
- Reducing environmental damage

➢ **Environment**

- Protecting air, water, and land ecosystems
- Preserving natural resources
- Protecting animal species and genetic diversity
- Use of renewable resources in great amount
- Preventing global warming

7. ***Benefits of Sustainability***

➢ **Social**

- Improved worker's safety
- Healthier lifestyle and work environment for workers

➢ **Economic**

- Compact work schedule
- Improved efficiency and productivity

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- Minimized construction costs
- Better product quality

➢ **Environment**

- Production of noise pollution and disturbance on site is reduced
- Reduced construction waste (debris is reduced in great amount)
- Wastage is controlled so the quantity of material is also reduced

8. ***Process Of Modular Construction***

The construction of modules is carried out in a factory in a controlled environment and about 70% work is completed in the factory. The major part of this process is the planning phase and various building codes are used to construct such structures.

❖ Concrete foundation is laid on site. At the same time, concrete foundations on site and modules on the factory are constructed.

❖ Firstly, the substructure is completed, and a base is prepared over which the prefabricatedmodules are constructed. Modules are built as per the architectural design.

❖ Modules can be placed side by side or can be stacked.

❖ Mechanical and electrical fixtures are either factory-installed or can be installed on-site.It is customized to the client's specifications.

❖ As the sections are manufactured in a factory, these sections are transported to the site using trucks or lorries.

❖ These modules are placed on the foundation using cranes.

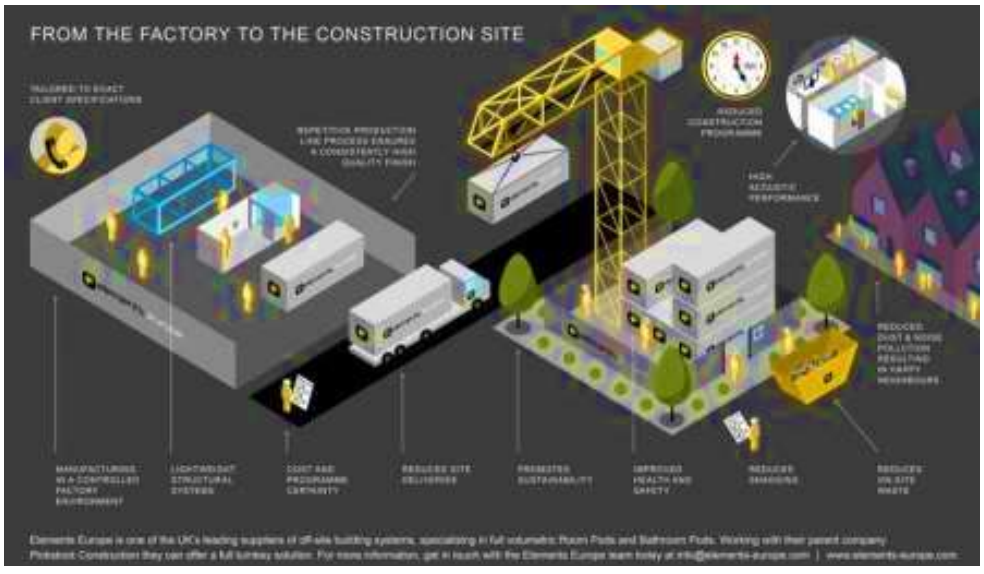

Figure 2 Process of Modular Construction

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9. *Financial Consideration of Modular Construction*

In Modular construction, most of the production takes place away from the construction site, and essentially the slow unproductive site activities are replaced by more efficient faster factory processes. Infrastructure for factory manufacturing requires higher investment in fixed manufacturing facilities, and repeatability of output to achieve economy of scale in production. Factors to be taken for an economic model for modular construction are:

- Advantages in speed of installation versus bounded change order opportunities.
- Manufactured volume (in context to economy of scale).
- Savings in site infrastructure and construction management.
- Proportion of on-site construction (in context to the total build cost).
- Transportation and installation costs.

Use of materials and wastage are decreased in huge amounts and productivity increased, but conversely, the fixed value of the productivity facility can be as high as 20% of the total built cost. The amount of on-site work is about 30% of the cost for a fully modular building, 30% broken down into foundations 4%, exterior finishes 13%, general services 7%, interior finishes 6%.

10. *Analysis of Modular and Traditional Construction*

Modular Construction	VS	Traditional Construction
Modular construction is a method in which buildings are designed in a factory, under regulated conditions, using the same building codes and standards as traditional construction.	**Introduction**	Traditional construction is defined by linear construction, in which each stage is not only built entirely (or nearly so) on-site but also must be completed before the project can progress to the next level.
Modular construction takes between 8 and 15 weeks to complete.	**Period of completion**	The period of completion of traditional construction can be 6-12 months or more than that.
In the design of a modular construction various aspects as involved such as the requirement of modular production, installation, and interface planning. It also involves economics and client-related needs, which affect the building's engineer and design	**Design and engineering**	The traditional construction is designed by the architects who were employed to design the building. The building is being constructed under the supervision of an engineer and an architect. The project depends upon the availability of materials,

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decision before construction. Since modular structures are highly flexible, changes in the interior and exterior appearances affect the building's design.		labour, weather conditions etc. Due to the longer duration taken by traditional construction, many changes are made as per the demand of the market and changes in technology.
The drilling, grading, levelling, and foundation laying on site are all performed in the same way as they are in traditional construction.	**Site development and foundations**	Excavation, grading, levelling, and base laying are all part of the site construction process.
Modular systems have the advantage of being conveniently extended, moved, and reused modules.	**Adaptability**	Adaptiveness Traditional structures are not as adaptable as modular modules; they are permanent and cannot be reused or moved.
In this construction, the construction time is very much less as compared to traditional construction, which makes it cost-effective construction. Modular construction reduces the cost of installation and assembly; thus, it helps the company owners save almost half of their building costs.	**Cost**	In this construction, the construction time is very much as compared to modular construction. This construction depends on various factors such as weather conditions, labour, codes of federal, state, and local levels etc. By considering these factors the cost increases more than the normal cost.
Modular structures are constructed in a factory environment. High-quality materials are manufactured. Due to the modular construction, 90% of wastage generation is reduced. The components are put together with the long-term efficiency of the finished product in mind.	**Sustainability**	In traditional construction, sustainability is dependent on the experience and skills of the contractor, engineer and architect. It is difficult to preserve the structure's sustainability due to frequent shifts in government policies.
		

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11. Conclusion

Modular construction achieves is a sustainable construction technique. Because it meets the criteria of sustainability's triple bottom line. It is socially, economically and environmentally beneficial. In this construction process, the wastage of material is decreased. Modules are constructed in a factory environment. It keeps track of the high-quality materials that are made. Waste production is decreased by 90% when construction is undertaken off-site. The components are put together with the long-term consistency of the finished product in mind.

In modular construction, the wastage of water is controlled. As the modules are prepared under high supervision. Production of noise pollution and disturbance on site is reduced. Reduced construction waste (debris is reduced in great amount). Wastage is controlled so the quantity of material is also reduced. Materials such as concrete are easily available and are considered sustainable materials which are easy to use. It is fire resistance. After installation of modules on site, no maintenance is required such as polishing or painting. Modular construction is a new way of achieving sustainability in building construction.

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