

## Analysing Modular Construction with Respect to Design and Cost

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**Abstract**— The aim of this work is to study the urban housing problem and provide a viable solution for housing shortage in India and to find out the cost effectiveness of modular construction, and analyzing it as a solution to efficiently and cost effectively boost multi-family housing production by taking advantage of the advances in manufacturing and transportation capabilities that several other sectors currently utilize. Modular construction is the most comprehensive production system of several which presently utilize factory assembly and manufacturing practices to produce housing. There are tremendous cost and time savings to utilizing this method.

**Keywords**:- Housing problem, Modular construction

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### I. INTRODUCTION

The term “modular” describes a construction method or process where individual modules stand alone or are assembled together to make up larger structures. Unlike relocatable buildings, PMC structures are intended to remain in one location for the duration of their useful life.

An important but subtle difference for this report is that modular construction refers to three-dimensional building “modules” that are prefabricated off site and transported to the site to make up the entire building, rather than prefabricated mechanical systems or wall assemblies.

Considering the housing shortage being faced in India right now, this could be a viable solution to be used in the housing projects for savings in cost and time. Even government rehabilitation schemes can make effective use of this method and provide the basic housing necessities at a lesser price.

The details of modular construction and its feasibility in the real estate sector is being elaborately discussed in the following pages, and this is a small attempt to throw light on the viability of the modular construction method as a the next step in modernizing construction and bringing on the new developments in the respective field.

### II. METHODOLOGY

- The first phase in this mini thesis is a thorough literature review explaining the modular construction, its benefits, cost analysis, comparisons and the basic understanding of the cost beneficial factors.
- In the second phase, after establishing a thorough understanding of the concept of modular construction and its different types, along with its benefits, a detailed survey is needed to be conducted to determine the state of modular construction in India, and this will involve visiting the sites, meetings with the respective heads of the various departments in various companies engaged in this method of construction. This data collection will also be supplemented by inputs from all the sources within the construction industry, and the general public as well to determine the public perception about this method. The necessary facts and figures to be collected will be collected from the data available through the above methods and also with the help of internet resources.

- The third phase begins with the end of data collection, and at this stage we analyze the received data, and compile it in a meaningful manner.

### III. AIM

The aim of this work is to find the cost effectiveness of modular construction, and analyzing it as a solution to efficiently and cost effectively boost multi-family housing production by taking advantage of the advances in manufacturing and transportation capabilities that several other sectors currently utilize. Modular construction is the most comprehensive production system of several which presently utilize factory assembly and manufacturing practices to produce housing. There are tremendous cost and time savings to utilizing this method.

### IV. OBJECTIVES

- To define modular construction and how modular construction can provide a solution for the housing shortage in India
- To establish the differences between the normal mode of construction and modular construction.
- To find out the economic feasibility of modular construction in the real estate sector of India and present its limitations
- To highlight the factors that lead to modular construction being a cost effective way of construction

### V. HOUSING SHORTAGE IN INDIA

Report of the Technical group on Urban Housing shortage (2012-2017) and working group on Rural Housing (2012-2017) submitted the same in 2011 to their respective ministries. Report estimated that almost a quarter of Indian households lack adequate housing facility. Country is on the verge of large scale urbanisation over the next few decades. As per 2011 census, country’s population was 121 crores and expected to reach 150 crores by 2050. Present urbanisation rate of 28% in 2011 is to accelerate to 52% by 2050. Urban population is expected to reach to 81 crores by 2050 as per “KPMG India Analysis July 2014”. Housing is a basic need for humans. Central Government acknowledges the importance of housing and aims to provide housing to its entire citizen by 2022. In order to fulfill this vision, 4.63 crores urban houses and 6.50 crores rural houses are required

to be constructed by Government, private sector and on public private partnership. Details of state wise urban and rural housing requirement are given in **Table ‘A’**

**Table ‘A’**

Details of Statewise Urban and Rural Housing Requirement  
(Figures are in lakhs)

Sr. No.	Name of State	No. of Urban Housing Units required in 2022	No. of Rural Housing Units required in 2022	Total Housing Units required by 2022
1	Uttar Pradesh	54	146	200
2	Madhya Pradesh	22	51	74
3	Rajasthan	21	45	66
4	Delhi	30	3	33
5	Haryana	11	14	25
6	Punjab	10	13	23
	<b>Northern Region</b>	<b>148</b>	<b>272</b>	<b>421</b>
7	Maharashtra	50	55	105
8	Gujarat	29	21	50
9	Goa	2	1	3
	<b>Western Region</b>	<b>81</b>	<b>77</b>	<b>158</b>
10	A.P. including Telangana	37	40	77
11	Tamil Nadu	39	18	57
12	Karnataka	28	21	49
13	Kerala	27	9	36
	<b>Southern Region</b>	<b>131</b>	<b>88</b>	<b>219</b>
14	Bihar	16	69	88
15	West Bengal	34	42	76
16	Orissa	9	26	35
17	Jharkhand	11	18	29
18	Chhattisgarh	8	14	22
	<b>Eastern Region</b>	<b>81</b>	<b>169</b>	<b>25</b>
19	Hilly Region	22	44	65
	<b>All India</b>	<b>4.63 crores</b>	<b>6.50 crores</b>	<b>11.33 crores</b>
20	Demand between 2014 and 2022	2.73 crores	2.70 Crores	5.43 crores
21	Urban Housing shortage of E.W.S. in 2012	1.055 crores		
22	Shortage of LIG in 2012	0.741 crores		
23	Shortage of M.I.G. in 2012	0.082 crores		
		<b>1.878 crores</b>		
24	Investment required upto 2022	1.80 Trillion Dollar	0.20 Trillion Dollar	2.00 Trillion Dollar

[Source: - Report of the working group on Urban Housing shortage (2012-2017), Ministry of Housing & Urban Poverty Alleviation working group on Rural Housing for XII Five Year Plan, Ministry of Rural Development 2011. Census 2011 KPMG in India Analysis]

**Note:** - Above estimate reveal that 75 percent of housing requirement

Until 2022 would be concentrated in ten states of U.P, Maharashtra, Bihar, West Bengal, Andhra Pradesh (including Telengna), Madhya Pradesh, Rajasthan, Tamil Nadu, Gujarat and Karnataka.

The total housing requirement of 11.33 crores by 2022 includes housing shortage of 5.90 crores as on 2014. The break-up of current housing shortage, requirement between 2014 and 2022 is given in **Table ‘B’** below:-

**Table ‘B’**

Sr. No	Particulars	Urban Housing Units in	Particulars Urban Housing	Total Housing Units in crores
1	Shortage of Housing Units in 2014.	1.90	4.00	5.90
2	Demand between 2014 and 2022.	2.73	2.70	5.43
	<b>Total</b>	<b>4.63</b>	<b>6.70</b>	<b>11.33</b>

[Source:-Report of Urban Technical Group (TG-12) on Urban Housing shortage (2012-2017), Ministry of Housing & Urban Poverty Alleviation September 2012.]

As many as 26 million homes are projected to be required by 2012 to meet the existing housing need, and 99 per cent of these homes are needed by households in the Economically Weaker Sector (EWS) and Lower Income Group (LIG). If the current increase in backlog of housing is maintained, a minimum of 30 million additional homes will be required by 2020. While some housing demand will be taken up within the existing housing stock, many millions of homes will need to be built across the country to fulfill the vision of becoming slum-free. Not only is the challenge to build many homes, but also to ensure that they are built at the right location, available at an affordable price to households that are in most need and of adequate quality to endure in the longer term.

Nearly 28 per cent of India’s population lives in cities and urban areas – double the level of urbanization at the time of Independence – a figure that is expected to rise to 40 per cent by 2020. The growing housing shortage is a culmination of the high rate of urbanization with a majority of housing stock catering to the premium segment, thereby incapacitating a large section of society from owning homes. The high cost of real estate, limited resources and inaccurate product offerings targeted at consumer groups have collectively contributed to the economically weaker sections and low-income groups being severely underserved.

As per the report of the Technical Group on Urban Housing Shortage, EWS/LIG houses constitute more than 95 per cent of the housing shortage in 2012 as per detail given in **Table ‘C’** below:-

**Table ‘C’**

Sr. No.	Classification of Housing Units	Number of Units in Million	Shortage in percentage term
1	Economically Weaker Section (EWS)	10.55	56.18

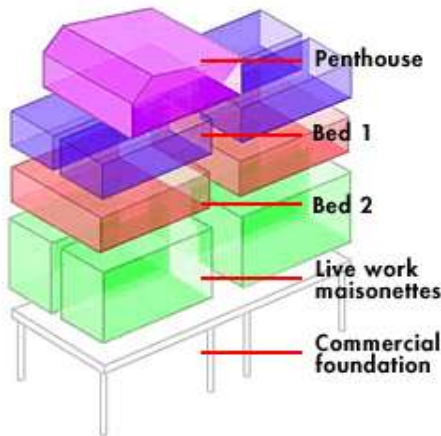
2	Low Income Group 7.41 39.44	7.41	39.44
3	Middle Income Group & above	0.82	4.38
	<b>Total</b>	<b>18.78</b>	<b>100</b>

[Source: - Report of the Technical Urban Group (TG-12) on Urban Housing Shortage 2012-2017. Ministry of Housing & Urban Poverty Alleviation September 2012.]

### VI. WHAT IS MODULAR CONSTRUCTION?

The term modular construction is used where a building is assembled from a series of volumetric steel modules, linked together to form a complete structure.

The modules, which are manufactured and finished (or partially finished) off-site, under factory conditions, are then transported to the building site and lifted on to pre-prepared foundations. The building is then connected to services and the exterior of the building dressed with cladding & roofing.



Modular construction is a more environmentally friendly method of construction than traditional techniques as minimal foundations are required for the installment/erection of and both modules and foundations can be prepared simultaneously, cutting construction times significantly. Importantly, as modules are produced under factory conditions, the likelihood of defects is minimized and better quality control is achieved.

While modular construction borrows techniques from the manufacturing industry, the end result does not look “mass produced”. Highly sophisticated structures can be produced which are easily customizable to suit individual requirements? Finishing with appropriate cladding and roofing allows the building to blend in with its surrounding environment.

### VII. COMPARISON BETWEEN MODULAR CONSTRUCTION AND TRADITIONAL CONSTRUCTION METHODS

	Modular buildings	Traditional construction methods
<b>Building codes</b>	Homes built in a factory and treated as traditional homes that follow the local building code and regulations.	Traditional homes are subject to the local buildings code and regulations.

<b>Floor Plans/Design</b>	Most builders can provide 100's of sample plans to help guide your home selection. Modular homes are normally highly customized in their interior and exterior appearances. Full custom modular builders, while rare, offer the ability to design from scratch or accept private architect's renderings for conversion by the factory to modular.	Most custom builders can provide sample plans they've built, offer design services, or direct you to plans on the Internet. In either case, Full customization is standard. Larger builders/developers offer select plans only for Their lots.
<b>Maintenance Cost</b>	Climate controlled indoor construction eliminates most weather-related problems, including black mold. Framing likely will never be exposed to direct moisture (rainfall). Manufacturers must over-build modular components to withstand highway travel to job sites. The resulting square/level/plumb structure is less prone to settling, cracks, and stress on components.	Since they are built on-site in all types of weather, the quality of the product varies greatly. In-the-field “modifications” mean lesser tolerances and more unknowns. Research has shown that traditional homes are more likely to require repairs and higher maintenance costs.
<b>Energy Efficiency</b>	Part of the over-building process for roadworthiness includes screwing and gluing drywall and sheathing for tensile strength and reduced racking. This creates a tighter building envelope that is draft-resistant and energy efficient. Heavier 2x6 exterior walls containing R19 insulation are standard, as are dual-panel windows w/low-E glass.	Choices run the full gamut. In order to compete with the economies of modular building, many stick builders will offer cheap “builder-grade” construction and material finishes.
<b>Greenness</b>	Because homes are built on an indoor assembly line, jobsite impacts (waste, soil erosion & destruction) are greatly reduced. Most factories are resource-efficient recyclers of scrap materials, and most can readily source “greener” product lines from their suppliers.	It is physically impossible to duplicate Indoor building outdoors.
<b>Resale Value</b>	Modular homes increase in value over time. Once they are completed it is near impossible to tell	Traditional homes will increase in value over time. They can be improved and expanded

	the difference between traditionally built homes and modular homes. These homes can also be improved or expanded.	to accommodate new owner's preferences.
<b>Timeframe</b>	This normal timeframe is 8-14 weeks. There are some time savings since construction can begin in the factory at the same time your foundation is being created on your site. Weather has almost no impact on the schedule.	The normal timeframe is 6-12 months. Since all construction occurs on site, work projects can not start until the previous project is completed. The work schedule is dependent on weather conditions.
<b>Appearance</b>	The same as any traditional site-built home. Any style of window, door, wall or architectural feature can be added.	The appearance can be customized to the home owner's preference. Traditional homes can accommodate any architectural preference.
<b>Building Process</b>	Assembly-line building. In a manufacturing factory. The removes delays cause by the weather and vandalism damages. This more efficient process reduces the cost when compared to traditional homes.	The most costly building process which requires almost the entire house to be custom constructed. It will require more people which will take more time since they do not work on the same type of house every day. It is also vulnerable to weather delays and vandalism costs. This process is the most likely to result in damaged building products like warped wood from rain exposure.

VIII. DESIGN PARAMETERS

The modular industry has benefitted greatly from advances in engineering and computer software. Design and customization that was once very difficult to accomplish has become much easier. A combination of modular and either panelized or site- built construction processes allow a developer to build almost any structure.

The real design limitations come from transportation regulations and from the structural nature of a modular box. The 16 foot width limitation makes it more difficult to create rooms with wide open spaces. The only real way to accomplish this is to combine two modules and open the walls between the two. If additional structural support is added then an opening of 16 foot is possible. Height limitations of around 13'6" including trailer, limit finished ceiling height to approximately nine feet. A 9'6" ceiling height is accomplished regularly with the use of a tray ceiling but this is the absolute maximum. Similar to site-built construction, the higher a ceiling is, the more expensive the building becomes to construct.

There is an incremental cost increase to expanding the width of a module being used for the construction, both in construction cost and because the unit will require transportation permits, off hour's shipment etc.

Modular construction is no different from that any other method in that a series of value engineering decisions must be made throughout the process.

IX. MODULAR CONSTRUCTION– THE COST EFFECTIVE CONSTRUCTION METHOD

Modular building is a remarkably cost-effective construction method. Concurrent construction allows work to begin sooner and in parallel with site preparation, which means cost savings at the outset. Modular structures require fewer calendar days to complete than conventionally constructed buildings. Precision fabrication allows design replication, so there is less material waste. Centralized factory manufacturing reduces energy consumption, building expenses and operating costs.

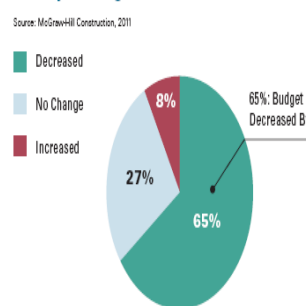


Quicker time to occupancy means greater productivity, income generation and improved cash flow for the end-user in any sector. For example, the sooner a medical center is completed, the sooner patients may receive health care; the quicker a school is opened, the faster students may begin learning.

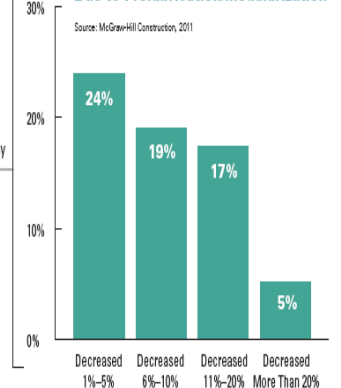
When the building is completed more rapidly, billing may commence sooner. Another advantage of modular building is flexible financing unique to this construction method, including off-balance sheet treatment of building assets and management of facilities as an operating expense rather than within capital budgets.

[Source-[http://www.dcd.com/insights/mayjun\\_2008.html](http://www.dcd.com/insights/mayjun_2008.html)]

Total Impact of Prefabrication/Modularization on Project Budget



Level of Decrease in Project Budget Due to Prefabrication/Modularization



X. MODULAR CONSTRUCTION SYSTEM

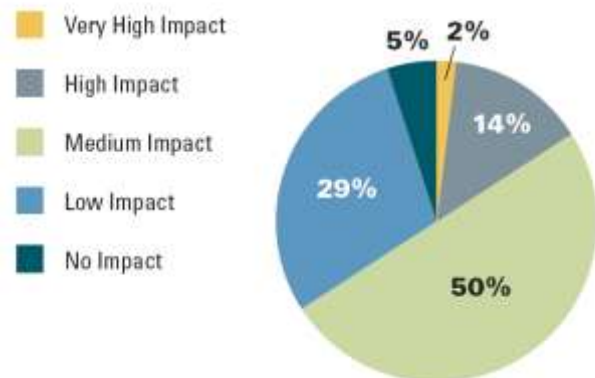
A building is termed as modular when manufactured and assembled in systematic way in factories rather than conventional methods of construction. (Note- In conventional construction system all the construction activities are performed on site.)

XII. COMPARISON BASED ON CAPITAL COST

Elements of construction	Traditional	Modular
External works and service connections	9	9
Foundations and sub structure	7	6
Framework and Floors	10	NA
Modular units (fully fitted out)	NA	50
Internal fittings	12	Included in units
Roof structure and roofing	5	3
External Cladding	15	10
Communal areas, access etc	8	8
Mechanical and Electrical services	15	5
Drainage and water	4	4
Site preliminaries	15	5
Total	100%	100%

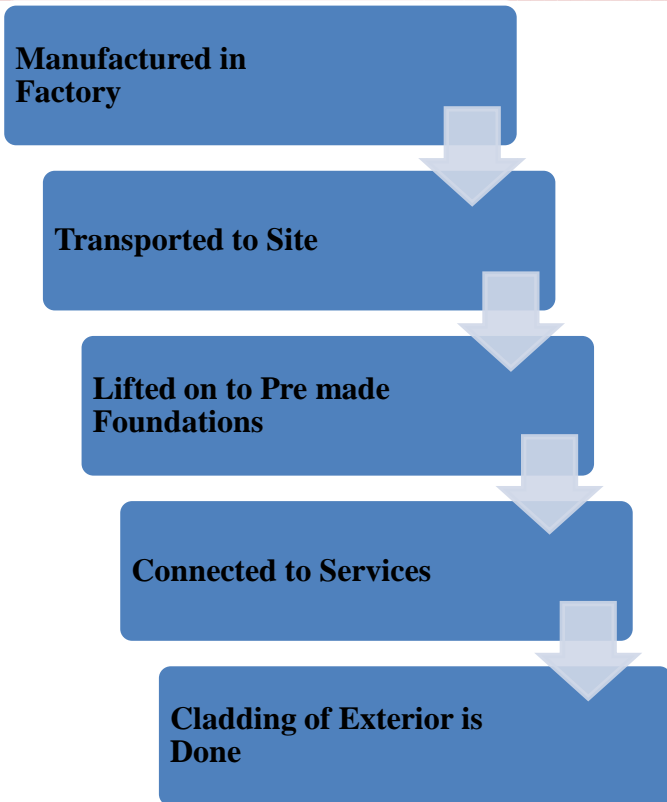
**Impact of Prefabrication/Modularization on Project Budget** (According to Non-Users)

Source: McGraw-Hill Construction, 2011

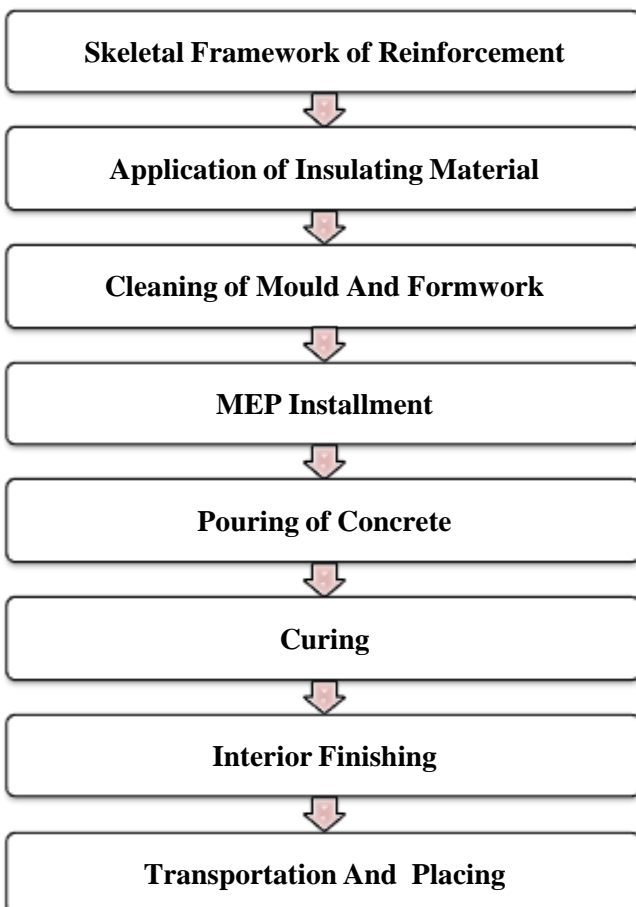


XIII. CONCLUSION

- Affordable housing with adequate facilities being the need of the hour.
- Modular buildings in general have the potential to benefit from higher quality with respect to improved material quality, improved building performance, sustainability, etc. In addition, production in factory environment results in higher worker productivity and a safer and healthier environment in modular construction compared with on-site construction.
- Modular construction allows for cost savings with crane and material rentals, General Conditions and General Requirements such as flagging and on-site offices, as well as a reduction in labor wages.



XI. PROPOSED METHODOLOGY FOR CONSTRUCTION



#### XIV. ACKNOWLEDGMENT

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Finally, I take this opportunity to extend my deep appreciation to my family and friends, for all that they meant to me during the crucial times of my project.

#### XV. REFERENCES

- [1] Builders' Association of India (All India Association of Engineering Construction Contractors & Builders)74<sup>th</sup> Annual Report and Accounts 2014–2015 [www.baionline.in](http://www.baionline.in)
- [2] Report of the Technical Group on Urban Housing Shortage (2012-17), Ministry of Housing and Urban Poverty Alleviation, Rural Housing for XII Five Year Plan, Ministry of Rural Development 2011; Funding the Vision - Housing for all by 2022, KPMG in India, 2014; KPMG in India analysis
- [3] A Modular Construction System How to design its Production Process Adaptable 2006, TU/e, International Conference on Adaptable Building Structures Eindhoven The Netherlands 03-05 July 2006 *F. van Gassel, M. Roders* Technische Universiteit Eindhoven PO Box 513, 5600 MB Eindhoven, The Netherlands
- [4] Value and benefits assessment of modular construction Modular Construction using light steel framing *A L ROGAN BSc PhD, FBEng, PEng, MCIQB, MAPM, MASI, R M LAWSON BSc (Eng), PhD*
- [5] Sustainable incremental house with modular construction. *CIB2010-W110-A4022 Eunike Kristi, JULISTIONO*
- [6] Modular Prefabricated Residential Construction Constraints and Opportunities August 2013 *PNCCRE Technical Report #TR002*
- [7] Mc Grawhill Conference manual 2011
- [8] R M LAWSON BSc PhD Ceng MICE MStructE MASCE ACGI The Steel Construction Institute Silwood Park, Ascot SL5 & QN [publications@steel-sci.com](mailto:publications@steel-sci.com) [www.steel-sci.com](http://www.steel-sci.com)
- [9] Modular Building: The Time and Cost Efficient Approach to Construction By *Joseph C. Lopardo* [http://www.dcd.com/insights/mayjun\\_2008.html](http://www.dcd.com/insights/mayjun_2008.html)
- [10] Modular Building: The Logical Choice *Joseph C. Lopardo* As seen in January-February 2008 issue of *The Military Engineer*, Vol. 100, Number 651, a magazine of the Society of American Military Engineers (SAME) <http://www.modular.org/htmlPage.aspx?HtmlPageId=459>