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"Evaluating Modular Construction: Effects On Timelines, Costs, And Resource Efficiency Using MS Project"

Adnya Manjarekar[1], Yash Anil Gadhave[2]
[1]Assistant Professor, Department of Civil Engineering, Sanjay Ghodawat University, Kolhapur, Maharashtra, India
[2] PG Student (CEM), Sanjay Ghodawat University, Kolhapur, Maharashtra, India
[1]adnya8111@gmail.com, [2]yashgadhave9701@gmail.com

Abstract
Modular building has become a revolutionary method in the construction sector, where it has provided both time and money comparatives by off-site pre-fabrication and onsite erection of building material. This paper is a critical assessment of modular construction compared to conventional practices on the basis of schedules, cost, technological limitations, and the adaptability within the industry. With the help of the Microsoft project (MS Project) as a project simulation tool, two models were formulated as a case model (modular and conventional), and the results were examined and measured to compare in terms of the differences experienced in time and cost. Project results indicate that the modular way helped in time savings of 66 days (13 percent), which took 425 days compared to the traditional method, which took 491 days. But it was more expensive at 13,840,920.00 against 12,975,900.78 because of prefabrication, logistics, and special labour; a premium of 6.67 percent. This notwithstanding, modular construction has strategic benefits for time-pressing projects. Surveys of stakeholders also revealed high initial cost of capital, shortage of skilled workforce, and regulation among the major obstacles to adoption. The relative importance index (RII) was used to express the gravity of the given barriers and to point out areas of intervention priorities. The research summaries that modular construction is a high-potential and scalable solution to the traditional model, especially with fast-track infrastructure. Nevertheless, it should be implemented successfully with the help of an augmenting ecosystem consisting of policy liberation, economic rewards, labor conveyance, and attention. Modular construction has a chance to become a seemingly universal solution in contemporary project delivery, given that the modular construction process requires suitable strategic assistance.
Keywords: *Modular construction, Project management, Time-cost trade-off, Barriers to adoption, MS Project simulation, Construction innovation.*

1. INTRODUCTION

The application of modular construction is currently undergoing in the construction sector, which means the construction is already facing a remarkable transformation where modular construction becomes a part of the industry and how the elements of the construction are created in a controlled off-site environment and then assembled at the site of construction.[1], [2]. The method is opposed to the old school model of construction, which is much more sequential and location-based. Among the benefits of modular construction are shortened delivery time, quality control, and fewer effects on the environment caused by minimization of site waste and effective use of resources [3], [4], [5].

In recent years, the building systems across the globe have been in need of solutions that were sustainable, economical, and time-effective, which has led to the rebirth of modular construction methods [6][7]. Research has revealed that the modular approach can decrease construction time by 50 percent and the cost by 20 percent on average, based on the extent of the work and the effectiveness of its implementation[4]. Moreover, modular construction is industrialized, which contributes to improved working conditions and minimizes risks of inefficient work in case of unfavourable weather conditions and shortages in the labour force, increasing productivity and safety respectively[3], [8]. Despite these advantages, challenges such as high upfront capital requirements, transportation logistics, and limited regulatory frameworks remain barriers to widespread adoption[8].

The research gap in this study arises from the lack of a comprehensive exploration into several key aspects of modular construction. First, while modular construction techniques have been discussed in various studies, there is a limited understanding of the specific challenges and constraints that come with modular construction when compared to conventional construction methods[9][10][11][12]. Second, although modular construction is often associated with time and cost efficiency[13], [14], [15]There is insufficient research assessing these factors using project management tools like MS Project to measure and compare time, cost, and resource efficiency in a structured manner. Additionally, while some research has touched on the adoption of modular construction[16], [17], [18], [19], [20], [21]The lack of knowledge about the perception of the stakeholders and what stands in the way of their universal acceptance exists. Last but not least, it is necessary that further analysis be conducted on the practicality of modular construction, especially with regard to how these challenges can be addressed, how to maximize efficiency, and how to generate better perceptions amongst the concerned parties in order to encourage wider adoption. Such gaps will be covered by the current study, which will examine the modular construction method, the evaluation of its efficiency, and the examination of stakeholders, as well as barriers to use.

This paper investigates the performance of modular construction in comparison to conventional techniques, with a specific focus on project timelines, budget implications, and resource management. It utilizes Microsoft Project (MS Project) as a project planning and analysis tool to simulate construction processes and optimize project delivery strategies.

Through the integration of technical literature, case studies, and survey-based data, the study aims to:

- Compare the outcomes of modular versus traditional construction approaches.
- Analyze the time and cost efficiency of modular construction using MS Project simulations.
- Examine stakeholder perceptions of modular construction and the barriers affecting its widespread adoption.

Additionally, the paper applies the Relative Importance Index (RII)[22]. To prioritize industry perceptions and obstacles, and provide practical knowledge about how to better practice modular building. These results can help to understand how digital project management processes can promote the development of modular construction and lead to making the construction sector more efficient and sustainable.

Microsoft Project (MSP) Overview

Microsoft Project (MSP) is a complicated working tool to handle the schedules of projects that fall between the low-tech methods and automated applications that orient the project planning. MSP adds features to CPM, which enables him to do things more accurately, much more flexibly, and efficiently compared to the traditional approaches, such as the CPM. It is the polar opposite of old-fashioned, time-consuming, error-prone methods that have been used, where MSP allows real-time creation, management, and monitoring of project schedules. It can enable us to define the tasks, establish relationships, resources, and manage and see how things are progressing without any hiccups. In reality, the project manager can make adjustments in the aspects of the work process accordingly to the adjustments in the subsequent project requirements using the features of automation. MSP is synchronized with the CPM to the extent that it determines the critical activities, calculates the float, and schedules the timeline in an excellent fashion, emphasizing the potential of delay[23]. Gantt charts and other computer-based plans and symbols like dials and simple options on charts allow the stakeholders to view the timelines and the efficiency of the resources, hence encouraging possible communication. MSPs are also equipped with other choices such as delay analysis, levelling of resources, cost control, and tracking, which fail to cut into most project management software, and thus they are critical in handling huge and multifaceted projects. All these features offered by MSP together in one interface allow teams to be responsive towards risks, increase their performance, and transition from traditional paper-based and static systems of managing projects to customizable, adaptable, and dynamic systems of project management. These three illuminated points have helped the MSP to develop itself as the most desirable system utilized by the construction experts [24], [25], [26]. By integrating dynamic scheduling with resource optimization with cost control & high value reporting, MSP transforms scheduling into more of a productive

and data-heavy process, which helps professionals in the construction line to undertake projects in a more modernised and controlled way, and more profitably as well[27], [28], [29].

2. Challenges And Constraints In Modular Construction

The research will take into consideration the survey information regarding the importance of modular construction in defining the major project aspects that are performance schedules, budget savings, and sources. Inception of the answers was determined by the Relative Importance Index (RII), whereby the values of the parameters were ranked according to their importance as perceived by the experts of the industry. A total of 51 responses were received.

Relative Importance Index (RII) is a statistical instrument utilized in ranking variables according to perceived importance of the respondents. It can be calculated by the formula: $RII = \sum W / (A \times N)$, where $\sum W$ is the total weight of all responses, A is the highest possible weight (5 for "Strongly Agree"), and **N** is the total number of respondents. The answers are collected with the help of 5 point Likert scale where 1 means (Strongly Disagree) and 5 remains (Strongly Agree). The resultant value of RII will lie between zero and one with higher values demonstrating high level of importance. The values of RII that range between 0.80 and 1 represent a very high importance, 0.60-0.79 denote a high importance, 0.40-0.59 imply a moderate importance, 0.20-0.39 signal low importance and less than 0.2 represents very low or no importance. This index can be used to rank the factors according to the perception of stakeholders in an orderly and measurable way.

Below table shows the summary of 22 questions in survey and their RII Index

Table No 1 RII Calculation

Question No	Questions	RII
1	Modular construction helps finish projects faster than traditional methods.	0.8784
2	Building with modular parts speeds up on-site work compared to regular construction.	0.8824
3	Making parts off-site (in a factory) helps the project move faster than building everything on-site.	0.8784
4	Design and building work can happen at the same time as site preparation, which saves time.	0.8392
5	Using modular parts helps reduce delays caused by weather or material problems	0.8392
6	Transporting modular parts to the site can cause delays that slow down the whole project.	0.7412
7	It can be hard to coordinate factory work with on-site work, which may cause delays.	0.7961
8	Delays in making or delivering modular parts can slow down the whole project.	0.8706
9	Saving time with modular construction helps keep the project within budget.	0.8706
10	Finishing the project earlier means the client can use the building sooner, adding more value	0.8824
11	Modular construction makes the building process more efficient than traditional methods.	0.8667
12	I would suggest using modular construction in future projects because it helps save time.	0.8431
13	Modular construction should be used more often in different types of projects to finish them faster.	0.8627
14	Modular construction allows better time management because the parts are standardized.	0.8471
15	The speed of finishing a modular project depends on how many skilled workers are available.	0.8784
16	Weather affects modular construction less than traditional building methods.	0.8196
17	Saving time with modular construction makes up for any extra costs.	0.7843
18	These projects need less supervision on-site, which lowers costs.	0.5490
19	Finishing projects faster helps developers and contractors make more profit.	0.8314
20	I think modular construction will become the main way to build faster in the future.	0.8196
21	As people get more experience with modular construction, it will become even quicker.	0.8627
22	Modular construction isn't used enough but could really help the industry work faster and better.	0.8588

Below table shows the Ranking of question according to their response

Table No 2 RII Ranking

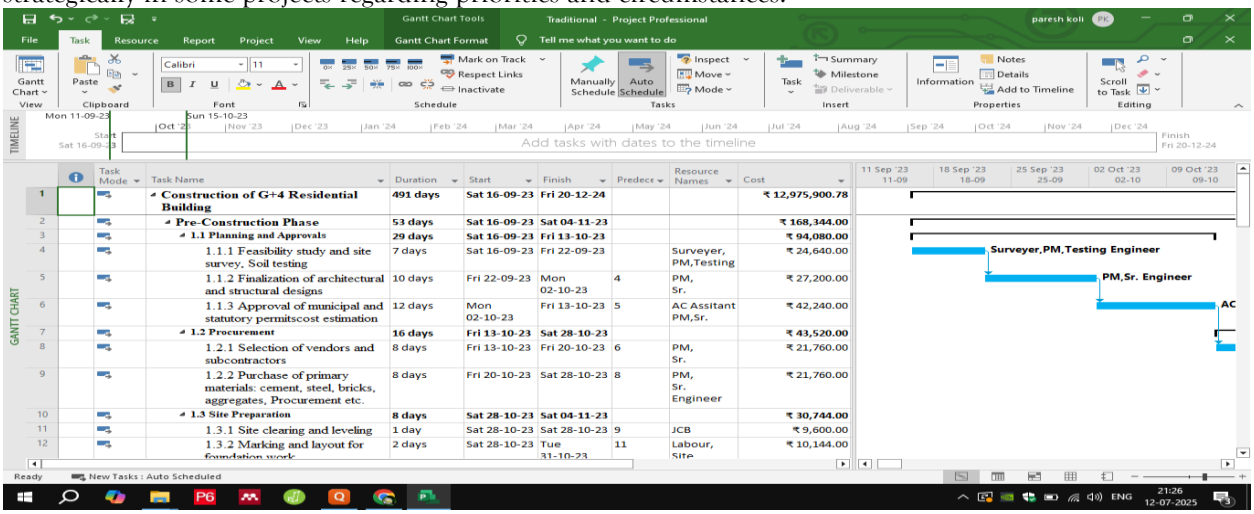
Question No	Questions	RII
2	Building with modular parts speeds up on-site work compared to regular construction.	0.8824
10	Finishing the project earlier means the client can use the building sooner, adding more value	0.8824
1	Modular construction helps finish projects faster than traditional methods.	0.8784
3	Making parts off-site (in a factory) helps the project move faster than building everything on-site.	0.8784
15	The speed of finishing a modular project depends on how many skilled workers are available.	0.8784
8	Delays in making or delivering modular parts can slow down the whole project.	0.8706
9	Saving time with modular construction helps keep the project within budget.	0.8706
11	Modular construction makes the building process more efficient than traditional methods.	0.8667
13	Modular construction should be used more often in different types of projects to finish them faster.	0.8627
21	As people get more experience with modular construction, it will become even quicker.	0.8627
22	Modular construction isn't used enough but could really help the industry work faster and better.	0.8588
14	Modular construction allows better time management because the parts are standardized.	0.8471
12	I would suggest using modular construction in future projects because it helps save time.	0.8431
4	Design and building work can happen at the same time as site preparation, which saves time.	0.8392
5	Using modular parts helps reduce delays caused by weather or material problems	0.8392
19	Finishing projects faster helps developers and contractors make more profit.	0.8314
16	Weather affects modular construction less than traditional building methods.	0.8196
20	I think modular construction will become the main way to build faster in the future.	0.8196
7	It can be hard to coordinate factory work with on-site work, which may cause delays.	0.7961
17	Saving time with modular construction makes up for any extra costs.	0.7843
6	Transporting modular parts to the site can cause delays that slow down the whole project.	0.7412
18	These projects need less supervision on-site, which lowers costs.	0.5490

The (RII) analysis is giving us an excellent idea regarding the level of appreciating different areas of modular construction by the professionals of the building/construction industry. The general conclusion regarding the findings would be that a modular building has a great chance of decreasing time which the project will consume and thus encouraging efficiency and striving towards an efficient use of time. In the score measure of RII, the figure demonstrates that most of the statements were well scored and this means that the level of intensity of the respondents who think that the modular approaches are considered to be such a desirable progress in the construction industry. And although such other barriers like difficulty in coordination or delay in transportation were pointed out, such problems were not deemed as being of high priority. Overall, the research indicates that the higher degree of interest can be observed in the modular type of development as a potentially helpful way of project delivery mode of the contemporary world. The RII values in the research were between 0.85 and beyond and it indicates that there is a large-level correlation between accepting the time-related and efficiency-related portions of modular construction in deciding the outcomes.

3. Impact Of Modular Construction On Project Timelines And Cost

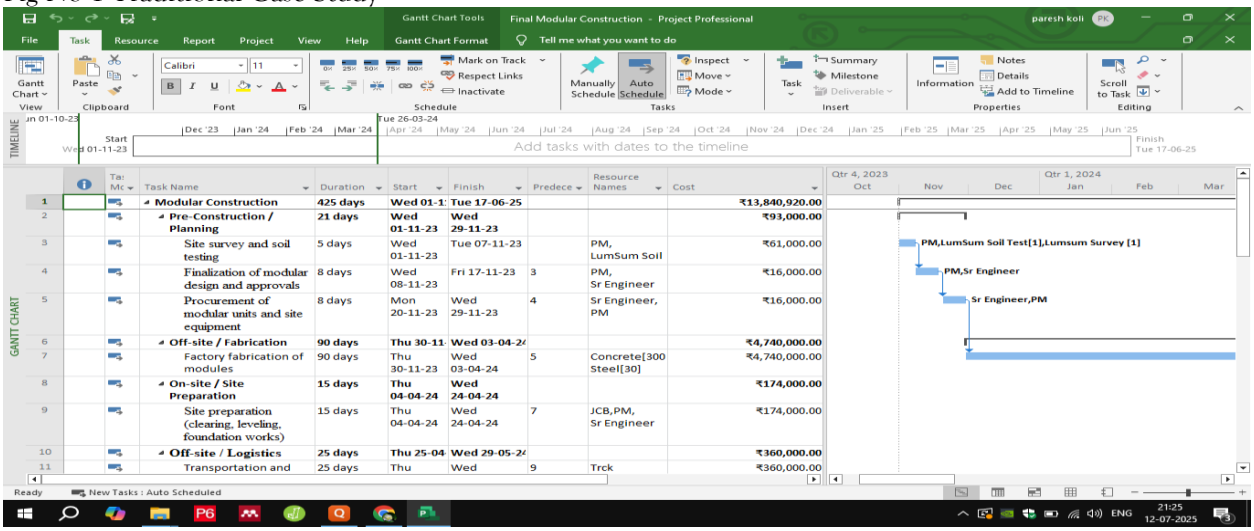
According to the identified methodology, the study is a comparative case study aimed at assessing the effects of modular construction on project schedules. Analysis of two construction projects completed in the real world was conducted with one relying on conventional construction process and the other on modular construction process. The traditional construction case has shown that there was a long project time of sequential activities carried out on the site and the delays caused by the weather. The modular construction case in turn showed a much more abridged schedule with the advantage of the off-site assembly and the

concurring onsite readiness. To be more precise, the modular project was finished 425 days after the start, whereas the conventional solution took 491 days, or 66 days less, or 13 percent improvement in schedule performance. This saved time was mainly contributed by the low on-site effort, control of disruptions and efficient timing facilitated by project planning tools such as MS Project. These case studies show concrete indications of the potentiality of modular construction to increase the speed of project delivering, confirm the industry perceptions that were collected by means of surveys, and prove the importance of off-site manufacturing as a method of minimizing the delays in construction. In addition to reducing project timelines, this study also examines the cost implications of modular construction compared to traditional methods. Although the modular construction case study demonstrated a shorter duration, it incurred higher overall costs. The total cost for the modular project was ₹13,840,920.00, whereas the traditional project cost was ₹12,975,900.78—resulting in a cost difference of ₹ 865,019.22. This premium price is most likely to remain at around 6.67 % mostly due to factory-based prefabrication, specialized transportation, crane logistics and skilled installations labour force needed in the assembling of pre-built modules on the sites. Short-term economic downsides in modular construction can be a lower initial investment, but long-term financial advantage in any project with short-term occupancy benefits, such as earlier revenue flows or lower financing costs, or with early completion benefits, like emergency construction, or commercial buildings. Thus, modular approaches will not always be the cost-effective on paper, but the time-cost tradeoff can be effective strategically in some projects regarding priorities and circumstances.



	Task Name	Duration	Start	Finish	Predece	Resource Names	Cost
1	**Construction of G+4 Residential Building**	**491 days**	**Sat 16-09-23**	**Fri 20-12-24**			**₹ 12,975,900.78**
2	**Pre-Construction Phase**	**53 days**	**Sat 16-09-23**	**Sat 04-11-23**			**₹ 168,344.00**
3	**1.1 Planning and Approvals**	**29 days**	**Sat 16-09-23**	**Fri 13-10-23**			**₹ 94,080.00**
4	1.1.1 Feasibility study and site survey, Soil testing	7 days	Sat 16-09-23	Fri 22-09-23		Surveyer, PM,Testing	₹ 24,640.00
5	1.1.2 Finalization of architectural and structural designs	10 days	Fri 22-09-23	Mon 02-10-23	4	PM, Sr.	₹ 27,200.00
6	1.1.3 Approval of municipal and statutory permitscost estimation	12 days	Mon 02-10-23	Fri 13-10-23	5	AC Assitant PM,Sr.	₹ 42,240.00
7	**1.2 Procurement**	**16 days**	**Fri 13-10-23**	**Sat 28-10-23**			**₹ 43,520.00**
8	1.2.1 Selection of vendors and subcontractors	8 days	Fri 13-10-23	Fri 20-10-23	6	PM, Sr.	₹ 21,760.00
9	1.2.2 Purchase of primary materials: cement, steel, bricks, aggregates, Procurement etc.	8 days	Fri 20-10-23	Sat 28-10-23	8	PM, Sr. Engineer	₹ 21,760.00
10	**1.3 Site Preparation**	**8 days**	**Sat 28-10-23**	**Sat 04-11-23**			**₹ 30,744.00**
11	1.3.1 Site clearing and leveling	1 day	Sat 28-10-23	Sat 28-10-23	9	JCB	₹ 9,600.00
12	1.3.2 Marking and layout for foundation work	2 days	Sat 28-10-23	Tue 31-10-23	11	Labour, Site	₹ 10,144.00

Fig No 1 Traditional Case Study



	Task Name	Duration	Start	Finish	Predece	Resource Names	Cost
1	**Modular Construction**	**425 days**	**Wed 01-11-23**	**Tue 17-06-25**			**₹13,840,920.00**
2	**Pre-Construction / Planning**	**21 days**	**Wed 01-11-23**	**Wed 29-11-23**			**₹93,000.00**
3	Site survey and soil testing	5 days	Wed 01-11-23	Tue 07-11-23		PM, LumSum Soil	₹61,000.00
4	Finalization of modular design and approvals	8 days	Wed 08-11-23	Fri 17-11-23	3	PM, Sr Engineer	₹16,000.00
5	Procurement of modular units and site equipment	8 days	Mon 20-11-23	Wed 29-11-23	4	Sr Engineer, PM	₹16,000.00
6	**Off-site / Fabrication**	**90 days**	**Thu 30-11-23**	**Wed 03-04-24**			**₹4,740,000.00**
7	Factory fabrication of modules	90 days	Thu 30-11-23	Wed 03-04-24	5	Concrete[300 Steel[30]	₹4,740,000.00
8	**On-site / Site Preparation**	**15 days**	**Thu 04-04-24**	**Wed 24-04-24**			**₹174,000.00**
9	Site preparation (clearing, leveling, foundation works)	15 days	Thu 04-04-24	Wed 24-04-24	7	JCB,PM, Sr Engineer	₹174,000.00
10	**Off-site / Logistics**	**25 days**	**Thu 25-04-24**	**Wed 29-05-24**			**₹360,000.00**
11	Transportation and	25 days	Thu	Wed	9	Trck	₹360,000.00

Fig No 2 Modular Construction Case Study

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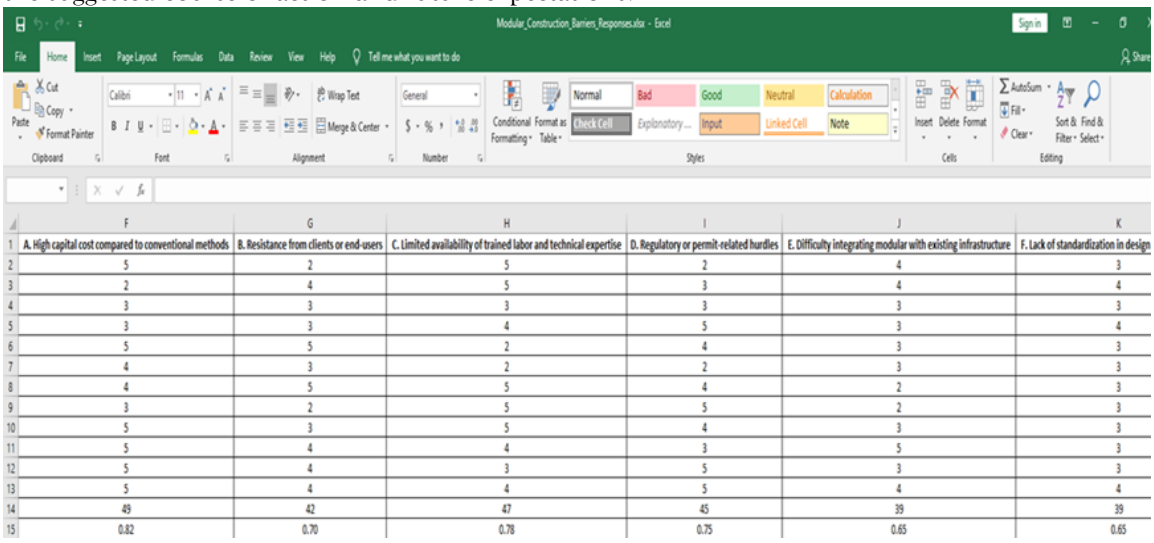
4. Barriers To Adoption Of Modular Construction

Modular construction has turned out to be a modern and industrial means of tackling some of the key issues raised in the construction industry such as delays, budget blow ups, and shortage of labor. Nevertheless, in relation to the technicalities, the modular construction has not been spared of some obstructions that hinder popularization. It is based on 12 developed responses based on Relative Importance Index (RII) technique to identify the level of seriousness of six major barriers along with qualitative options of the most serious barriers, the suggested course of action and future expectations.



	F	G	H	I	J	K
1	A. High capital cost compared to conventional methods	B. Resistance from clients or end-users	C. Limited availability of trained labor and technical expertise	D. Regulatory or permit-related hurdles	E. Difficulty integrating modular with existing infrastructure	F. Lack of standardization in design
2	5	2	5	2	4	3
3	2	4	5	3	4	4
4	3	3	3	3	3	3
5	3	3	4	5	3	4
6	5	5	2	4	3	3
7	4	3	2	2	3	3
8	4	5	5	4	2	3
9	3	2	5	5	2	3
10	5	3	5	4	3	3
11	5	4	4	3	5	3
12	5	4	3	5	3	3
13	5	4	4	5	4	4
14	49	42	47	45	39	39
15	0.82	0.70	0.78	0.75	0.65	0.65

Fig No 3 RII of barriers selected by respondents

5.1 Top 3 Barriers Selected by Respondents

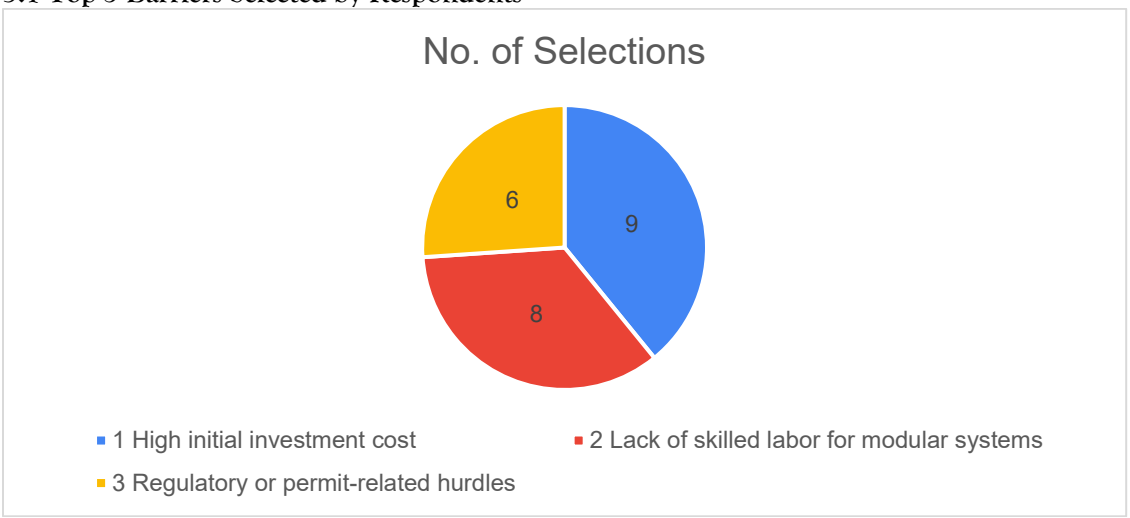


Fig No 4 Barriers selected by respondents

5.2 Barrier Analysis

A. High Capital Cost (RII = 0.82)

- Modular construction requires significant upfront investment in design, prefabrication, and logistics.
- The cost of lifecycle might be cheaper but the developers are in fear of this as they have fewer finance facilities..

B. Limited Skilled Labor (RII = 0.78)

- Independence of factory workers and module assembly technicians are not allowed because of shortage of factory trained workers which this has affected quality and efficiency
- On-site teams often lack experience with modular integration.

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C. Regulatory Hurdles (RII = 0.75)

- Building codes are outdated and incompatible with off-site production or hybrid-constructive model..
- Approval processes delay modular project timelines.

D. Client/User Resistance (RII = 0.70)

- Market perception that modular buildings are "low quality" or "temporary" still exists.
- Design flexibility is often misunderstood.

E & F. Integration & Standardization (RII = 0.65 each)

- Legacy infrastructure Integration challenges may arise when module sizes are not of standards and hence will not fit in, well.
- The lack of modular design standards limits supplier coordination and cost savings.

5.3 Interventions to Remove Barriers

They were asked about the interventions that they think might be effective, and respondents chose several. This is a list of most popular strategies:

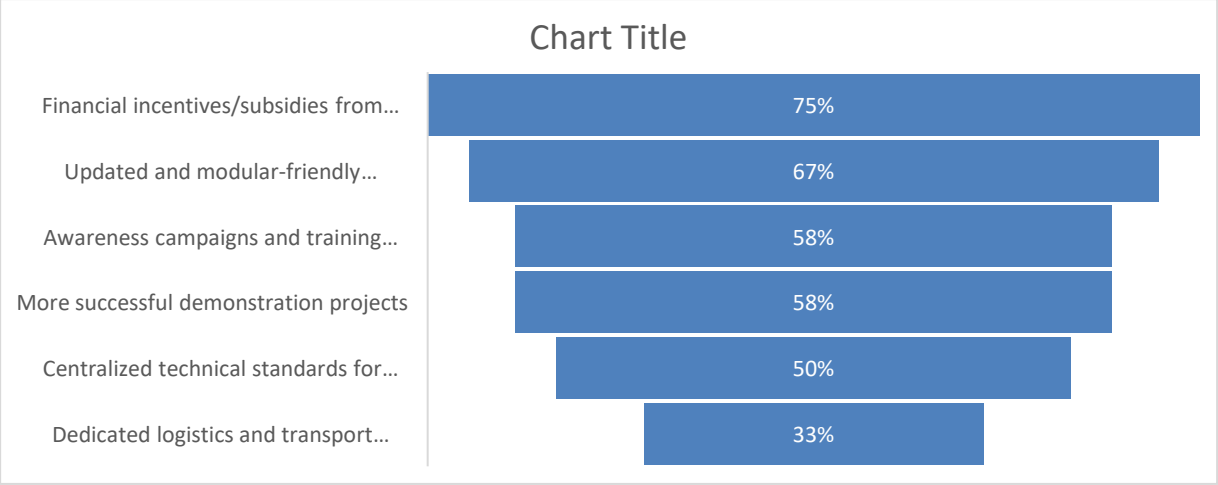

Fig No 5 Barriers selected by respondents

The input of government in the areas of provision of resources in form of finances, regulation support as well as creating awareness, training with the objective of overcoming resistance to develop a trained workforce is imperative.

5.4 Outlook on the Future of Modular Construction

When asked about their general outlook, responses were distributed as follows:

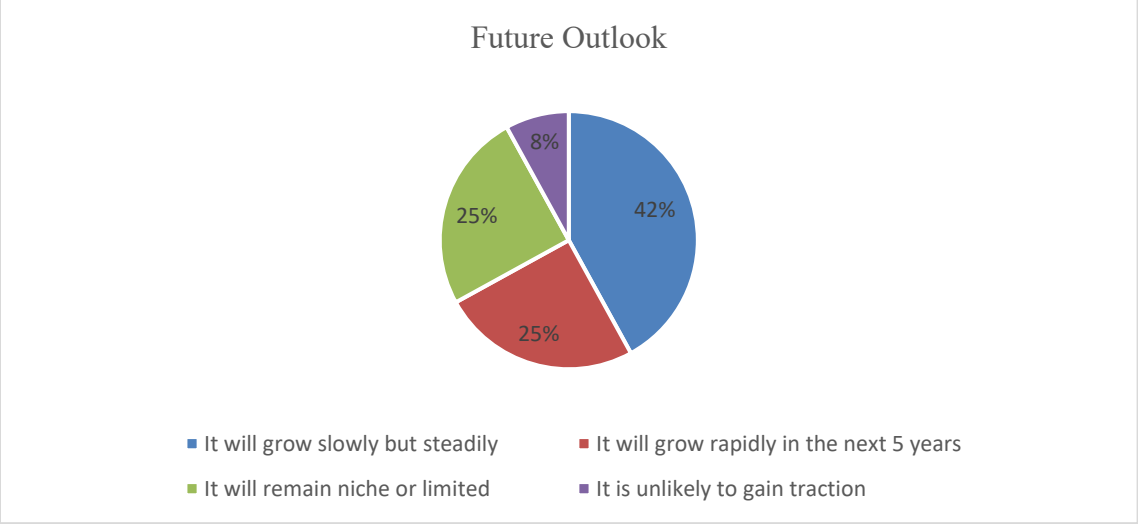

Fig No 6 Future Outlook

5. RESULT AND DISCUSSION

This Section consolidates the results of modular construction project simulation and compares its performance with that of traditional processes, as well as provides an interpretation of the findings within the framework of industry issues and stakeholder attitudes and the following strategic implications. The interview has its foundation on quantitative evidence, expert opinion and industry wide trends.

6.1 Project Performance: Time and Cost

Modular construction gave a record of 425 days compared to 491 days in a traditional construction 66 days (13% faster) due to the simultaneous off site and on-site work. Nonetheless, this saved time was offset by an additional expense in modular construction of 13,840,920.00 as compared to the traditional method of 12,975,900.78 with a difference of 865,019.22. Additional cost was mainly caused by prefabrication, transportation logistics and special labour. Early completion can be economically beneficial in projects where time is very critical like in the healthcare sectors or commercial ventures despite the premium.

6.2 Technical and Operational Constraints

There were also a number of logistical and technical difficulties in modular implementation. As opposed to conventional builds, modular constructions presuppose rigged timing of factory and site. The city locations had a limited spatial range, the transportation and assembly logistics of modules required specialization. These limitations point to the fact that it is necessary to plan a construction project with pre-construction precision since it is hard and expensive to change plans in the middle of an ongoing project.

6.3 Timeline Efficiency

The survey results prove that modular construction could dramatically shorten projects. Factory conditions, able to be controlled, are able to protect critical path against weather and labour interruption. The major strength of the prefabrication system is that off-site manufacture and site assembly are made possible at the same time, thus delivery happens sooner with no quality loss. This allows early takeover and war preparedness with strategic and financial advantages.

6.4 Barriers to Adoption

Despite its benefits, modular adoption is held back by systemic barriers, including:

- High upfront capital costs
- Shortage of skilled modular labor
- Regulatory uncertainty

All these, these intertwined issues restrict adoption even in the face of funding. The feedback on surveys and literature indicate that the form of resistance is not related to mistrust in the technology but rather on lack of adequate infrastructural support and policies to progress.

6.5 Strategic Interventions and Outlook

Respondents emphasized the need for:

- Economic incentives
- Policy reform
- Training programs
- Demonstration projects

While cost remains a concern, confidence in execution and regulatory clarity were equally valued. Most professionals believe modular construction will grow steadily, particularly in sectors like affordable housing and social infrastructure. A smaller group expects faster adoption if supported by government or private flagship projects.

CONCLUSION

This study has critically examined the feasibility of modular construction to conventional construction on the basis of timelines, economy of costs, challenges of execution, and acceptance by the market. Combined simulation-based planning, cost analysis, and stakeholder surveys, the results prove the point that modular construction has distinct benefits, along with the concerns, which can be managed.

The modular construction took 66 days lesser than the conventional approach, thus the project was completed in 425 days compared to 491 days. Though it suffered a cost premium of ₹865,019.22 rupees, it was attributed to prefabrication, logistics as well as specialized labour. The incremental cost is reasonable in time pressure projects whereby the completion of the project earlier leads to a value addition.

But the study also showed implementation difficulties, among which were the requirement of exact logistics, troubles at confined locations, and the inability to change anything when production starts. These obstacles point towards the mental change that needs to happen, namely being more planning and industrialization than improvisation during the making process on the ground. Further analysis through survey revealed high-cost of capital, limited availability of skilled labour, as well as regulatory uncertainty as amongst the main factors hindering adoption. Nonetheless, prospects are bright and it is anticipated that the industry will grow steadily as prophesied by the professionals; particularly in areas, such as housing and healthcare industries.

Evidence abounds that intervention measures like policy change, financial incentives, uniform practices and campaigning need to be pursued. These point to the necessity of an extensive ecosystem in order to promote scalable modular adoption. To sum up, modular building is not a single technological variant, but the prospective alternative to working in the manner typical of the past. Its flaws of initial expenditure and integration will persist, but its importance as related to swifter, uniform, and quality development features makes it highly applicable in a construction environment that would be more orientated toward efficiency and eco-efficiency. Modular construction can take on the mainstream with the appropriate strategic help.

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