



**Keywords:** Off-site construction; Construction industry; Housing; Modular Construction; Indian construction; Readiness maturity model

## Introduction

Slow adoption of new and innovative technologies is one of the significant reasons that the construction sector usually lags behind other industries to take full advantage of innovations [1,2]. However, this trend has been changing over recent years, especially regarding Off-Site Construction (OSC) awareness and its importance. OSC has received broader acceptance in many countries; however, it is still a comparatively recent phenomenon and yet to gain momentum in India [3]. India has started to consider using OSC practices in recent years. Innovation in the construction industry has often been observed as slow-moving; in India's case, the technological 'conservatism' further hinders the shift towards new methods and innovative practices [4].

Sustainability was not the top priority in India; however, the construction sector is slowly becoming sustainable; the past decade has witnessed massive growth in this area, becoming one of the top issues in the sustainable development program 2030 and the exploration and innovation of the construction industry [5-7]. However, the most significant barrier is the increasing need for infrastructure and housing in India. Other factors and the construction sector face include delays in completion, low quality, high demand, and lack of project management skills, which hinder the construction industry's consistency and growth [8].

standardisation and reduce cost and time [12-15]. Several authors, have looked at the drivers and challenges faced by the OSC in India and how to mitigate them [3,16, 17]. They have highlighted several issues and solutions and stressed the need to investigate further the aspects that affect people, processes, and organisations. Recent studies in India reported a lack of international exposure to construction activities, especially in large scale projects and physical infrastructure development [18]. Other points include the dominance of traditional practices that are highly labour-intensive and uncertainty in cost and time schedules [19,20]. Therefore, it is critical to address the high demand for housing, infrastructure, global knowledge transfer and a sustainable built environment in India.

The literature review highlighted the significance and benefits of employing OSC methods; however, the current uptake of OSC is low in India but is gradually increasing. The literature review also suggests no clear evidence of successful OSC implementation in the Indian context because it is highly competitive. Companies only search for proven technologies to gain a competitive advantage [21]. Things have been changing for the last few years. Some organisations have started considering OSC as an alternate and innovative technique. However, issues such as lack of guidelines, awareness, and resources to implement it efficiently. Hence, there is a need for tangible evidence of the advantages of using different OSC techniques levels. Researchers from other practising nations such as the UK, USA, Australia, China and Malaysia have documented the experiences and lessons regarding OSC in the literature. Still, there is a strong need for tangible research [22].

Many researchers have looked at the OSC adoption in different developed countries; some highlighted the critical role of strategy in implementing OSC. The project strategy is essential to changing the project process from 'traditional construction' to 'manufacturing



F2.3.Shortage in availability: How does the organisation overcome the shortage of OSC products due to lack of local manufacturers?	Does the organisation address the encountered challenges in procuring OSC products?	Does the organisation supplement imported products with locally manufactured products?	Does the organisation comprise an in-house facility or collaboration with foreign manufacturers, to transfer and utilise their technology?
F2.4. Availability of codes/standards: The extent to which the organisation provide guidelines to the designers, operators and another construction workforce.	Are there any written standards/guidelines available to all the members in the project team?	Does the organisation strictly follow the standards throughout the design and construction stages?	Does the organisation document the instructions before design and monitor the activities to ensure compliance with the standards?
F2.5. Maximising environmental performance In the life cycle: To examine the strategies deployed by the organisation to maximise the usage of sustainable products and processes in various projects.	Does the organisation decide to adopt sustainable products that are sustainable? If yes. Does it prioritise the usage of sustainable products?	Does the organisation decide to adopt sustainable practices (selection of sustainable products, minimising waste during construction, etc.) at the beginning of the project?	Does the organisation establish a policy products recommended by standard Organisations? Does the organisation also register for sustainable building
Does the organisation allocate dedicated funds to support and accelerate preparedness of the organisation in terms of capital investment?	Does the organisation allocate dedicated funds to support and accelerate techniques?	If yes, does the organisation maintain a	Does the organisation establish a strategies? Also, does it critically evaluate the business patterns and revise their investment strategies?
<b>F3.Certainly in planning</b>			
F3.1.Cost certainly: To what extent does the organisation plan and monitor the budget performance?	Does the organisation document the		

spread throughout India. In the recent five years, they have constructed administration and accommodation complexes for various academic

### Factor 1.6. Client's Resistance and Scepticism

During the interviews, it was noticed that organisation X is yet to face any significant resistance from its clients. According to the project manager, the client approached the organisation with a prior decision on the implementation of OSC. The on-going project has clear timelines and completion targets at the project briefing and initial discussion stages. So, the selection of OSC methods was encouraged by the client. One of the senior managers expressed a similar opinion about the stadium project. Organisation X maintains documentation of the project all through the phases. It was noticed that the documentation of the critical benefits of OSC was performed in various projects. However, it was difficult to assess the organisation's readiness against the construct, "resistance and scepticism" only based on the on-going projects. Hence, the authors explored the documented and archival evidence. On several occasions, the organisation details the success stories of previous projects to their extensive client base. The organisation encourages clients to participate in vigorous brainstorming and all critical decision-making events. Therefore, it can be said that organisation X reached level three of the OSC readiness in terms of "Client's Resistance and Scepticism."

### Factor 1.7. Guidance and Information

Different learning materials were identified along with the know-how, guidance charts on display in the site office and other construction site locations. According to the project manager and an HR manager, the organisation encourages the manufacturers/vendors to train their workforce. However, there is no standard practice or setup for training, unlike some other case studies. The project manager expressed his opinion that providing an in-house instructor or trainer would enhance construction performance and speed. According to him, this was already put up to HR and management. The HR manager shared that the organisation is considering addressing this in their annual plan for the next financial year. From the above interview and observations, it can be concluded that organisation X is currently at level two concerning 'guidance and information that fosters readiness in adopting OSC methods.

## Factor 2. Building Readiness

**Factor 2.1. Transportation Infrastructure:** According to the operations managers and senior project managers, the management acknowledges the significance of transportation infrastructure. In the interview, all the participants expressed that the project team evaluates the available infrastructure during the project feasibility analysis. It is one of the critical components of technical feasibility. Such an initial analysis provides the necessary information on the existing transportation infrastructure. The operations manager pointed out that all the OSC intense projects are located in prime locations with adequate infrastructure. She further highlighted that a detailed route plan and schedule would be prepared twenty days before the products' arrival. As discussed in the earlier section (Factor 1.2.), the organisation has a dedicated team to plan the operations and logistics. This team handles all the critical decision making and liaising with various agencies and stakeholders. Based on these findings, the researcher assigned level three to the organisation in terms of "Transportation Infrastructure."

**Factor 2.2. Material Selection:** In the interviews, all the participants stated that they finalise the product selection and prepare all the estimation documents at the project's early stages. The procurement and logistics team prepare a critical evaluation report at the early stages. It was observed that the project teams approach the OSC intense projects with an appropriate supply chain and timescale.

This entire process is treated as an integral part of the design and construction phases. In the senior operations manager's words, "we select supply chain with right skills and experience." Organisation X visited the manufacturing units in China before the selection. The interviews revealed that the organisation only works with vendors who express willingness to abide by a legal contract. Therefore, level two is assigned to the organisation in terms of "Manufacturing Facility."

**Factor 2.3. Shortage of Suppliers:** According to the senior project manager, the organisation acknowledges the shortage of suppliers and prefabricated solutions manufacturers. In his words, "It is high time for the company to begin an in-house facility. The future of housing is prefabricated. If the management aspires to capture the market, we must invest our money in wise infrastructure." From the interview findings, it can be concluded that the current organisation lacks an in-house manufacturing facility. It imports materials and products for large scale projects. Therefore, organisation X can be assigned level one for this factor.

**Factor 2.4. Availability of Codes and Standards:** According to the senior management, the architects and design team provide requirements and standards (as per the local legislation and building codes) to the manufacturers. The manufacturers share the product plan, features, and material specifications. In the interview, the project manager commented, "The imported products generally present detailed guidelines and standards. At present, there are no restrictions or standards specified for prefabricated construction. The government may think about this". The evidence of detailed guidelines and codes of practice were observed during the site visit. Hence, organisation X is at level three in the readiness to adopt OSC in the area "Availability of Codes and Standards."

**Factor 2.5. Maximising Environmental Performance in the Lifecycle:** Most of the participants acknowledged that off-site products possess efficient, environmentally friendly features. The architects mentioned a different, perhaps a contrary opinion. A few architects from the design team commented, "There is no product in the market that says unsustainable. Sustainability is linked to the process of construction and life cycle of the building". During the interviews, the author collected a mixed response to the sustainability aspect. However, all the participants (design and execution) expressed that the organisation follows a clear waste minimisation strategy. Based on the pieces of evidence, it can be stated that the organisation attained level two in the area of "Maximising Environmental Performance in the Lifecycle."

**Factor 2.6. Capital Cost:** The senior project manager and HR manager conveyed that organisation X is considering upskilling the workforce. HR also mentioned that the management is committed to additional budget allocation under the training and learning overhead. However, the researcher could not access more data on the cash flows since the financial documents are treated as confidential and sensitive documents. The operations manager hinted on the future expansion, in-house facility, and other collaborations with Asia's manufacturers. However, this is unclear as a committed expenditure is not observed. According to the findings, it can be understood that the organisation is at level one in terms of the "Capital Cost" factor.

## Factor 3. Construction Readiness

**Factor 3.1. Cost Estimation:** The interviewed participants expressed that the QS team prepares detailed estimates and quantities for all the initial phase projects. As the authors could not interview the organisation's finance managers, the manager operations shared

moderate information on the organisation's finance and cost planning. According to him, the finance managers work in coordination with various teams of different projects. The finance managers monitor and document the general administrative expenses, contract-related costs, project cost, financing-related costs (cost of capital), and internal accounting. The project manager shared that a weekly accounting review and financial reporting are practised in the on-going project. He shared, "This helps us in keeping track of all expenses and projected costs, payments, and in mitigating risks if any". Based on the findings, the researcher assigned level two against the "cost certainty" factor.

**Findings 3.2. Time Management:** The senior project manager stated that the project planning team prepares the project schedule in consultation with the manufacturers, vendors, and suppliers; organisation X has an established protocol for all the OSC intense projects. In such projects, the project team pays attention to the critical activities and time-cost

readiness framework was applied carefully in organisation X to evaluate operational efficiency. The findings demonstrated that all organisations X had achieved level two of OSC readiness in "Prompt delivery" [42-47].

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Current research and literature on OSC do not adequately assess the OSC readiness of construction organisations in India. Successful implementation of OSC highly depends on the organisation's readiness, and the organisations must be aware of their current strengths and weaknesses. Previously, there was no formal assessment method to evaluate the OSC readiness of the company at an organisation level. Although there were several maturity models, they could not help organisations level up and enhance their OSC readiness and implementation. The appropriation of maturity levels provides clear guidance and direction into the practical stages and issues needed for construction entities to maximise their OSC engagement within the Indian market. This also provides suitable direction and measures for evaluating and benchmarking their processes (strategic and operational) against core phases. The corollary enables organisations to evaluate their OSC 'preparedness' or readiness for engaging in the OSC market. Therefore, exercising this research has helped fill the gaps identified in India's literature and the OSC section. Hence; an OSC readiness maturity model would be influential for the initial assessment of India's construction organisations' OSC preparedness. This maturity model will serve as a guide for OSC practitioners, policymakers and other key stakeholders involved in improving the construction industry's quality in any country with similar demographics and conditions. The research has made a significant contribution to two aspects of current knowledge. The study primarily established a set of 4 key areas that need to be considered at the organisational level while implementing OSC. Secondly, the research developed the OSC readiness maturity model to assess India's construction organisations' readiness status. The research will add to the existing body of knowledge on OSC by mapping issues relevant to India's construction industry.

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