Off-Site Construction Implementation in Bangladesh: A Qualitative Study

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Abstract: Off-site construction (OSC) offers significant potential to improve efficiency and quality in the construction industry. However, its adoption remains limited in developing countries like Bangladesh. This study aimed to identify key barriers to OSC implementation in Bangladesh and propose strategies to overcome these obstacles. Semi-structured interviews were conducted with 15 construction professionals, including contractors, consultants and government officials. The data was analysed using thematic analysis. Results indicated that the main barriers included a lack of awareness and understanding among stakeholders, insufficient government support, inadequate skills and training, limited transportation infrastructure, high initial costs, resistance to change, a lack of local manufacturing capacity and insufficient collaboration between industry, government and educational institutions. Key strategies for improvement included comprehensive education and training programmes, supportive government policies and incentives, investment in transportation infrastructure, development of local manufacturing capabilities, promotion of research and innovation, implementation of risk management strategies and streamlining of environmental clearance processes. This study provides valuable insights for policymakers and industry leaders to facilitate the adoption of OSC in Bangladesh's construction sector.

Keywords: Off-site construction, Bangladesh, Construction industry, Prefabrication, Barriers

INTRODUCTION

Off-site construction (OSC) has been referred to by several names in various literature, including modern method of construction, prefabricated construction, precast construction and industrialised building system (IBS) (Arif et al., 2012b; Mohammad et al., 2016). OSC is also referred to as prefabricated construction, modular construction, modern methods of construction or off-site manufacturing, which involves constructing buildings or their components in a factory setting. These prefabricated elements are then transported to the construction sites for assembly (Jin et al., 2018). OSC represents a significant advancement in the global construction industry, offering a modern approach that leverages manufacturing efficiencies to streamline the building process. By allowing construction activities to

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occur simultaneously in a controlled factory environment, OSC enhances productivity (Assaad et al., 2022b; Jang et al., 2021), reduces waste (Jin, Hong and Zuo, 2020; Lu et al., 2021) and shortens project timelines (Jung and Yu, 2022; Shahzad, Rajakannu and Kordestani Ghalenoei, 2022). These benefits address some of the most pressing challenges in the construction sector, including quality control and project delays.

According to Sutrisna, Ramnauth and Zaman (2022), a modern construction method can potentially address speed expectations and quality issues in the global construction industry. Globally, OSC has been widely used as a highly effective construction method for delivering projects. Assaad et al. (2022a) mention that OSC benefits the construction workforce, including enhanced productivity, improved working conditions and increased competencies and safety levels. Moreover, Lu et al. (2021) compared conventional construction with prefabricated components and the result logged a 15.38% waste reduction when utilising OSC. This study confirmed the positive effects of prefabrication on waste minimisation and articulates that two types of prefabricated components play relatively more significant roles in minimising construction waste.

However, in developing countries, like Bangladesh, the adoption of OSC remains limited (Datta and Assafi, 2022). Despite the rapid growth of Bangladesh's construction sector, which has seen the completion of numerous megaprojects, traditional, labour-intensive methods continue to dominate (Chowdhury, 2022). Datta and Assafi (2022) found that in Bangladesh, no specific construction method was identified as OSC, even though it was found that some projects had applied prefabricated components (Datta and Assafi, 2022). Additionally, Chowdhury (2022) mentioned that the concept of OSC is comparatively new. Though there were many research studies conducted on the barriers to OSC, prior research was not specifically focused on the context of Bangladesh (Datta and Assafi, 2022; Chowdhury, 2022). Due to the lack of research on OSC in Bangladesh, this research intended to close the gap. Specifically, this study aimed to identify the key barriers to OSC implementation and proposed strategies to overcome them. By examining the perceptions and experiences of construction professionals in Bangladesh, this study sought to provide insights that could pave the way for the broader adoption of OSC in the country's construction industry, ultimately contributing to more efficient, sustainable and high-quality construction practices.

LITERATURE REVIEW

In many countries, OSC is known for its capacity to deliver high-quality results, thus has become an integral part of the construction landscape. The barriers to the adoption of OSC are also well-researched. Table 1 illustrates that prior

studies had determined the 15 most common barriers to implementing OSC in different countries.

Table 1. Barriers to OSC implementation

Factors	Sources
Market demand uncertainty	Arif et al. (2012a); Mao et al. (2013); Rahman and Asce (2013); Gan et al. (2018)
Market and public lack of awareness of OSC	Arif et al. (2012a); Mao et al. (2013); Gan et al. (2018); Li, Zhang and Meng (2021)
Inadequate application from local projects	Zhang, Skitmore and Peng (2014); Gan, Chang and Wen (2018); Zhang and Yu (2021); Beulah (2022)
Dependency on conversational construction methods	Pan, Gibb and Dainty (2012); Mao et al. (2013); Gan et al. (2018); Sutrisna et al. (2019)
Inadequate local R&D institutes and services	Blismas and Wakefield (2009); Mao et al. (2013); Zhang, Skitmore and Peng (2014); Gan et al. (2018); Musa et al. (2018); Salama, Moselhi and Al-Hussein (2021); Abd Razak et al. (2022)
Transportation of prefabricated elements	Jaillon and Poon (2010); Mao et al. (2013); Rahman and Asce (2013); Zhang, Skitmore and Peng (2014); Charlson and Dimka (2021); Song et al. (2021)
Struggle to store prefabricated components	Jaillon and Poon (2010); Mao et al. (2013); Zhang, Skitmore and Peng (2014); Gan et al. (2018); Hwang, Shan and Looi (2018); Almashaqbeh and El-Rayes (2022)
Lack of skilled workforce	Muhammad et al. (2016); Musa et al. (2018); Abdul Hamid (2019); Razkenari et al. (2020); Abd Razak et al. (2022); Assaad et al. (2022b)
Lack of design standards for prefabricated process	Mao et al. (2013); Muhammad et al. (2016); Gan, Chang and Wen (2018); Musa et al. (2018); Sutrisna et al. (2019); Salama, Moselhi and Al-Hussein (2021); Beulah (2022); Jung and Yu (2022)
Lack of governmental rules and encouragement	Pan, Gibb and Dainty (2012); Mao et al. (2013); Gan, Chang and Wen (2018); Musa et al. (2018); Abdul Hamid (2019), Salama, Moselhi and Al-Hussein (2021)
High initial cost	Arif et al. (2012a); Sutrisna et al. (2019); Charlson and Dimka (2021); Almashaqbeh and El-Rayes (2022)
Client conservatism and uncertainty	Pan, Gibb and Dainty (2012); Gan, Chang and Wen (2018); Gan et al. (2018); Musa et al. (2018); Sutrisna, Ramnauth and Zaman (2022)

Mao et al. (2013) identified a lack of market demand as one of the major barriers to OSC adoption in China. They found that developers hesitated to invest in OSC due to market acceptance and demand uncertainties. Gan et al. (2018) established that a lack of market demand was a key barrier, interlinked with other factors such as high initial costs and a lack of skilled labour. Without a steady demand for prefabricated components, manufacturers were reluctant to invest in the necessary technology and infrastructure (Arif et al., 2012a). In addition, Rahman and Asce (2013) identified market uncertainty as one of the key barriers to implementing modern methods of construction, including off-site and prefabrication techniques.

Next, a lack of public awareness was identified as one of the significant barriers to OSC adoption. Limited understanding of OSC benefits among the public and potential buyers hindered market demand (Mao et al., 2013). Gan et al. (2018) used interpretive structural modelling to analyse barriers to OSC in China. The lack of awareness was a key barrier, interlinked with other factors such as resistance to change and limited market demand. Arif et al. (2012a) noted that a limited understanding of OSC benefits among stakeholders impeded its adoption. In addition, Li, Zhang and Meng's (2021) findings reinforced the notion that insufficient consumer awareness and market demand are critical obstacles to adopting prefabricated buildings. This lack of awareness affected and influenced the decisions of potential buyers and stakeholders within the construction supply chain. This led to a cycle of underutilisation of prefabrication technologies.

One of the primary barriers to the effective application of prefabrication in local projects was local contractors' limited experience and familiarity with OSC. Many construction professionals relied heavily on traditional construction methods, leading to hesitancy in adopting prefabrication techniques that require a different skill set and operational approach (Beulah, 2022). This lack of familiarity resulted in project delays, increased costs and, ultimately, a failure to realise the potential benefits of prefabrication. Additionally, integrating prefabricated components into traditional construction processes posed significant challenges. Discussion on prefabricated construction required a shift in supply chain management and project planning, which many local projects cannot handle (Zhang and Yu, 2021). The complexity of coordinating between factory production and on-site assembly led to logistical issues, further complicating the application of prefabrication in local settings. Datta and Assafi (2022) identified the lack of local project applications as a barrier to OSC implementation in Bangladesh. The author noted that the limited use of OSC in local projects contributes to a lack of practical experience and knowledge among construction professionals. A study by Zhang, Skitmore and Peng (2014) found that the inadequate application of OSC in local projects in China was a significant obstacle to its wider adoption. The lack of successful local case studies made it difficult for stakeholders to assess

the benefits and risks of OSC implementation. Moreover, Gan, Chang and Wen (2018) highlighted that the limited application of OSC in local projects in China created a barrier to its adoption. The scarcity of local examples made it challenging for developers and contractors to gain confidence in OSC methods.

The dependence on conventional construction methods was a significant barrier to adopting OSC. Mao et al. (2013) identified dependence on traditional construction methods as one of China's top three barriers to OSC adoption. The study determined that developers were reluctant to shift from familiar conventional methods to newer OSC techniques. Gan et al. (2018) used Interpretive Structural Modeling to analyse barriers to OSC adoption in China. They presented that the reliance on traditional construction methods was a key barrier, interlinked with other factors such as lack of awareness and resistance to change. The resistance to change was compounded by the fact that many stakeholders are accustomed to traditional procurement routes, which do not align well with the operational requirements of OSC (Pan, Gibb and Dainty, 2012). Moreover, the inertia in adopting OSC methods could be attributed to the perceived risks associated with transitioning from conventional practices. Sutrisna et al. (2019) highlighted that actors in the construction industry often prefer to stick with well-established methods and materials, primarily due to uncertainties regarding costs and the performance of new technologies. This risk aversion can lead to a cycle where innovation is stifled, as stakeholders are hesitant to invest in unfamiliar approaches that deviate from traditional construction practices. In conclusion, the dependence on conventional construction methods significantly limits the adoption of OSC techniques. This reliance is driven by established norms, perceived risks and a lack of familiarity with off-site technologies, all creating substantial barriers to innovation in the construction industry.

The inadequacy of local research and development (R&D) institutes and services was identified as a significant barrier to the adoption of OSC. This limitation manifested in various ways, impacting innovation, technical support and industry advancement. Zhang, Skitmore and Peng (2014) highlighted the lack of local R&D support as a challenge to industrialised residential buildings in China. The study noted that insufficient R&D resources hindered innovation and adaptation of OSC techniques in local contexts. Similarly, Mao et al. (2013) emphasised that limited local R&D capacity restricted the ability to optimise OSC methods for specific regional needs. Gan et al. (2018) examined that inadequate R&D support was a key barrier, interlinked with other factors such as lack of technical standards and limited innovation capacity. In the Australian context, Blismas and Wakefield (2009) identified limited R&D investment as a constraint to the wider adoption of off-site production. The lack of comprehensive R&D efforts hindered the industry's ability to address the specific needs and challenges of local markets (Salama, Moselhi and

Al-Hussein, 2021). This limitation affects not only technological innovation but also workforce development. Musa et al. (2018) assessed that the successful implementation of IBS required skilled professionals, which was challenging without adequate training programmes and resources provided by local R&D institutes.

Another significant barrier to the adoption of OSC was the transportation of prefabricated elements. Mao et al. (2013) identified transportation constraints as a major obstacle in China, noting challenges related to the size and weight of prefabricated components. Transportation difficulties arise from limitations in road infrastructure and transportation regulations (Zhang, Skitmore and Peng, 2014). Rahman and Asce (2013) noted the need for specialised vehicles and careful route planning when transporting large, prefabricated elements. Meanwhile, Jaillon and Poon (2010) stressed the importance of considering transportation limitations in the design phase of prefabricated elements. Beyond these logistical challenges, Charlson and Dimka (2021) highlighted the high costs associated with transporting large, prefabricated components, which deterred clients from adopting OSC methods. Song et al. (2021) emphasised the impact of freight mode selection and transportation efficiency on the overall cost and quality of prefabricated building elements. Additionally, Kurpinska, Grzyl and Kristowski (2019) raised concerns about the environmental impact of transporting these components, including increased carbon emissions.

Moreover, the struggle to store prefabricated components was a significant barrier to adopting OSC. Hwang, Shan and Looi (2018) identified limited storage space at construction sites as a major constraint, especially in dense urban environments. On the other hand, Zhang, Skitmore and Peng (2014) and Gan et al. (2018) emphasised the lack of storage space for large, prefabricated elements as an important barrier in China, noting that it disrupted the supply chain and installation schedule. Jaillon and Poon (2010) identified the storage of prefabricated components as a key design issue in Hong Kong, while inadequate storage space was a major barrier from the developer's perspective (Mao et al., 2013). Alternatively, Beulah (2022) highlighted how limited storage space led to construction delays, while Almashaqbeh and El-Rayes (2022) discussed the risk of damage to prefabricated components during storage.

The lack of skilled construction workers in prefabrication was another significant barrier to adopting OSC methods. Abdul Hamid (2019) emphasised that transitioning to IBS required a workforce well-versed in modern construction practices. Meanwhile, Muhammad et al. (2016) highlighted how the limited availability of skilled labour led to delays and cost overruns. Successful prefabrication implementation relied on integrating various disciplines, which is challenging without skilled professionals (Abd Razak

et al., 2022). Many construction firms did not prioritise training in modern methods, perpetuating reliance on outdated practices (Musa et al., 2018). This skill shortage affected project quality, efficiency and innovation in the construction industry. Assaad et al. (2022b) further emphasised that the lack of specialised skills for OSC environments led to substantial cost and schedule overruns.

The lack of design standards for prefabricated processes significantly hindered the adoption of OSC. This issue was particularly pronounced when prefabrication was not yet fully integrated into the construction industry. For instance, the absence of standardised design protocols led to inconsistencies in the quality and compatibility of prefabricated components, resulting in increased costs and project delays (Musa et al., 2018; Salama, Moselhi and Al-Hussein, 2021). Furthermore, the lack of experience among project participants in Designing for Manufacturing and Assembly (DfMA) exacerbates these challenges, as many stakeholders are not adequately trained to address the unique requirements of prefabricated construction (Beulah, 2022; Jung and Yu, 2022). Sutrisna et al. (2019) and Mao et al. (2013) indicate that integrating design standards is crucial for enhancing the efficiency and effectiveness of OSC processes, as it facilitates better planning and coordination among various stakeholders. Without these standards, the potential benefits of OSC, such as improved productivity and reduced waste, remain largely unrealised (Muhammad et al., 2016; Gan, Chang and Wen, 2018).

The lack of supportive governmental regulations and encouragement significantly hinders the adoption of OSC. Research indicates that governmental policies are crucial in facilitating the transition to these modern construction methods. For instance, the United Kingdom government has recognised the potential of OSC to address housing shortages. However, it has been criticised for insufficient policy frameworks that would effectively promote its widespread adoption (Salama, Moselhi and Al-Hussein, 2021). Similarly, in Malaysia, while the government has introduced the concept of IBS, the lack of systematic tools and collaboration among stakeholders has been identified as a barrier to its implementation (Musa et al., 2018; Abdul Hamid, 2019). Furthermore, Gan, Chang and Wen (2018) and Mao et al. (2013) highlight that without clear governmental incentives and regulations, the construction industry relies heavily on traditional methods, limiting innovation and efficiency. The absence of a robust policy environment stifles investment in OSC and perpetuates a cycle of conventional practices that are less sustainable and less efficient (Pan, Gibb and Dainty, 2012). Thus, enhancing governmental support and establishing comprehensive regulations are essential for overcoming these barriers and fostering a more conducive environment for OSC practices.

The high initial costs associated with OSC represent a significant barrier to its widespread adoption in the construction industry. Research indicated that clients often perceived OSC as more expensive than traditional construction methods, which deterred investment despite its potential long-term savings and efficiencies (Arif et al., 2012a; Charlson and Dimka, 2021). For instance, Charlson and Dimka (2021) highlighted that the lifecycle costs of offsite projects, which include design, manufacturing and installation, led to initial expenditures that are substantially higher than conventional approaches. Additionally, cost uncertainty remained critical as stakeholders often hesitate to transition from established methods due to the financial risks involved (Sutrisna et al., 2019). This reluctance was compounded by the perception that initial cost reductions and customisation benefits were not sufficiently compelling to justify the upfront investment in OSC technologies (Arif et al., 2012a). Consequently, addressing the high initial costs through strategic financial incentives and clearer cost-benefit analyses was essential for promoting the adoption of OSC practices in the construction sector (Almashaqbeh and El-Rayes, 2022).

Client conservatism and uncertainty posed significant barriers to the adoption of OSC. Clients often preferred traditional construction methods due to their familiarity and perceived reliability, which led to resistance against innovative approaches, like OSC (Sutrisna, Ramnauth and Zaman, 2022). This conservatism was compounded by uncertainties surrounding the performance and quality of prefabricated components, as clients feared that these new methods could compromise project outcomes (Gan et al., 2018). Additionally, the lack of established benchmarks and proven case studies further exacerbated this uncertainty, making clients hesitant to invest in OSC despite its potential benefits (Musa et al., 2018). Research conducted by Pan, Gibb and Dainty (2012) indicated that clients were likely to remain sceptical, stalling the broader implementation of these advanced construction techniques without adequate education and demonstration of successful OSC projects. Consequently, addressing client concerns through targeted outreach and showcasing successful OSC applications is essential for overcoming these barriers and fostering greater acceptance within the industry (Gan, Chang and Wen, 2018).

METHODOLOGY

This study employed a qualitative research design to explore the awareness, barriers and potential strategies for implementing OSC in Bangladesh. Qualitative research was chosen due to its effectiveness in providing in-depth insights into complex social phenomena and understanding the perspectives of construction professionals within their natural settings. The study specifically

utilised a semi-structured interview approach. The approach was well-suited for exploratory research where the goal was to gather detailed information from participants with varying levels of experience and understanding of OSC.

Research Population and Sampling

The research targeted professionals involved in the construction industry in Bangladesh, including contractors, consultants and government officials. These individuals were selected based on their involvement in decision-making processes related to construction methods and their potential influence on the adoption of OSC. The sampling method employed was purposive sampling, allowing the selection of participants with specific knowledge relevant to the study's objectives. Purposive sampling, also known as judgmental, selective or subjective sampling, reflects a group of sampling techniques that rely on the judgement of the researcher when it comes to selecting the units (e.g., people, case/organisations, events, pieces of data) that are to be studied (Sharma, 2017). This approach ensures that the data collected is rich in context and directly applicable to the research questions.

A total of 15 participants were interviewed for this study, representing a cross-section of the construction industry in Dhaka, Bangladesh. The sample size was determined based on the principle of data saturation, which suggests that qualitative research can be considered sufficient when additional interviews no longer provide new insights or themes. This sample size was consistent with qualitative research norms and deemed appropriate for this study's scope.

Data Collection

Data was collected using semi-structured interviews that were conducted both in-person and online, depending on the availability and preference of the participants. The interview questions were developed based on an extensive literature review on OSC. They were designed to probe participants' perceived barriers to its implementation, as well as potential strategies for overcoming these barriers.

The interview guide included open-ended questions to allow participants to express their views freely and provide detailed responses. Examples of questions included: "Are you aware of OSC as a modern construction method?" and "What do you see as the main challenges in adopting OSC in Bangladesh?". Each interview lasted between 45 minutes and 60 minutes, and all interviews were recorded with the participant's consent to ensure data capture accuracy. The list of participants is shown in Table 2.

Table 2. List of participants

Code	Participant's Organisation	Position	Years of Experience
P1	Ferro Build	Civil engineer	> 8 years
P2	BEPZA	Sub-assistant engineer	> 8 years
P3	Credence Holding Limited	Chief design co-ordinator	> 8 years
P4	HBRI	Research associate - Structural engineering and construction division	> 8 years
P5	Evergreen Design & Construction	Civil engineer	> 8 years
P6	KDC Consultant	Design engineer	> 8 years
P7	Dhaka Design & Construction	Structural engineer	> 8 years
P8	BIONICS Concrete Chemical Company Ltd.	Sales development manager	> 8 years
P9	Arif Building Design Consultancy	Civil engineer	> 5 years

Data Analysis

The collected data were transcribed verbatim and analysed using thematic analysis, a method appropriate for identifying, analysing and reporting patterns (themes) within qualitative data. The analysis was conducted using NVivo software, which facilitated the organisation and coding of data. Thematic analysis was chosen because it allows for a detailed examination of the data, enabling the researcher to identify key themes related to OSC awareness, barriers and strategies.

The analysis process involved several steps:

1. Familiarisation with the data: This step involved reading and re-reading the transcripts to become deeply familiar with the content.
2. Generating initial codes: Codes were generated from the data, focusing on interesting features that could inform the research questions.
3. Searching for themes: Codes were collated into potential themes, then reviewed and refined to ensure they accurately represented the data.
4. Defining and naming themes: Each theme was clearly defined and named, with supporting data extracts to provide a rich, detailed account.

RESULTS AND DISCUSSION

The data from the interview questions was analysed to answer the research objective. The interview questions were evaluated on two primary topics: (1) implementation barriers and (2) strategies for improved OSC implementation. The data were summarised in the results and discussion section.

Barriers to Off-Site Construction Implementation

Understanding of off-site construction among the construction players of Bangladesh

The interview responses from construction players in Bangladesh revealed a consensus that the understanding of OSC among stakeholders was insufficient. Participants consistently indicated a lack of knowledge and familiarity with OSC, emphasising the need for enhanced education and training to improve this situation. This finding aligns with existing literature highlighting the importance of stakeholder collaboration and education in successfully adopting innovative construction methods. For instance, Gan, Chang and Wen (2018) emphasised that the construction industry, characterised by fragmentation and conservatism, required effective stakeholder engagement to facilitate the diffusion of OSC technologies. Similarly, Pan, Gibb and Dainty (2012) discussed the need to integrate strategies to help stakeholders transition from conventional methods to OSC, underscoring the need for a comprehensive understanding of the benefits and processes involved.

Moreover, the interview responses suggested that the high initial costs associated with OSC contributed to the reluctance of stakeholders to embrace OSC, as they often failed to perceive its long-term benefits. This observation was supported by research by Charlson and Dimka (2021), indicating that clients frequently viewed OSC as a more expensive option than traditional construction methods, which hindered its adoption. Additionally, the literature concluded that a lack of established benchmarks and proven case studies exacerbates client uncertainty, further complicating the decision-making process. In addition, the need for targeted education and training was echoed in the literature. This finding suggested that enhancing the knowledge base of construction professionals and workers is crucial for the successful implementation of OSC (Assaad et al., 2022b). The participants noted that a systemic change in the construction industry was necessary to actualise OSC's full potential. This aligned with the findings of Sutrisna, Ramnauth and Zaman (2022), who argued that innovative construction methods require a shift in the overall approach to construction practices. In conclusion, the insights gathered from the interviews highlighted a critical gap in understanding OSC

among construction players in Bangladesh, necessitating focused educational initiatives and stakeholder collaboration to foster a more informed and receptive environment for OSC practices.

Government support and incentives for the adoption of off-site construction

The analysis of government enthusiasm for OSC in Bangladesh indicated a lack of strong commitment. Participants generally agreed that the government was not enthusiastic about implementing OSC. Clear declarations or policies were absent in supporting this modern construction technology, making it an open field for exploration. If a company wished to introduce new construction methods, there was neither guidance nor prohibition from the government. Datta and Assafi (2022) found that the absence of guidelines related to OSC led to low OSC. P4, a participant from a government agency, mentioned that there were plans to incorporate modern construction methods in specific projects. However, no official decisions had been made regarding the choice of methods or the timeline for their implementation. This suggested that while there was some interest, they had not yet been translated into concrete actions or policies.

The adequacy of skills in implementing off-site construction among construction players

The interview responses regarding the adequacy of skills among construction players in Bangladesh for utilising OSC revealed a significant consensus that current skill levels were insufficient. Participants indicated a lack of adequate skills attributed to several factors, including limited training opportunities, inadequate awareness of OSC practices and the high initial costs associated with adopting new technologies. This aligned with findings from Assaad et al. (2022b), who emphasise the critical need for targeted training and skill development to enable the workforce to effectively implement OSC practices. Moreover, the participants' comments reflected a recognition that while the current skill set was inadequate, there is potential for improvement through focused training initiatives. This perspective was supported by research by Ginigaddara et al. (2023). They indicated that structured training programmes bridged the gap between conventional construction techniques and the requirements of OSC, enhancing productivity and quality on construction sites. Hence, the need for a systematic approach to training is critical, whereby the successful adoption of OSC relies heavily on the workforce's ability to adapt to new methods and technologies (Sutrisna, Ramnauth and Zaman, 2022). Despite these challenges, there was a consensus that skills could be developed through targeted training and education. Participants suggested that the partnerships between the government, educational institutions

and industry players could facilitate the acquisition of necessary skills. This approach could help bridge the gap and make OSC a viable and efficient option in Bangladesh's construction sector.

The readiness of the construction industry in Bangladesh to accept new methods

The analysis of the construction sector in Bangladesh regarding its readiness for modern construction methods, such as OSC, revealed a mixed perspective among industry participants. Some believed Bangladesh was financially prepared but lacked technical readiness, while others believed both financial and technical readiness as achievable with targeted interventions. This study found that some participants believed Bangladesh was financially prepared to adopt OSC due to the country's significant economic growth and investments in infrastructure and the construction industry, supported by strong domestic demand and substantial investments from both the public and private sectors. The focus on mega infrastructure projects in Bangladesh, such as the Padma Bridge and Metro Rail, reflected a solid financial commitment to modernising the country's infrastructure. The Padma Bridge, in particular, is expected to significantly impact the national economy by enhancing connectivity and boosting GDP. It is anticipated to increase Bangladesh's annual GDP by 1.23% and has already generated substantial revenue through toll collections since its opening (Jalil and Mia, 2021; Sourav, Afnanin and Islam, 2023). Additionally, these projects are part of Bangladesh's broader strategy to enhance its transport network and infrastructure, aiming to sustain higher economic growth levels and position the country as an investment hotspot in South Asia. This financial strength is further bolstered by international aid and foreign direct investments, which provide the necessary funds for modernisation (World Bank Group, 2021). This financial strength is bolstered by international aid and foreign direct investments, which provide essential resources for modernisation.

There is a consensus that while financial readiness was present, technical readiness was lacking. Participants highlighted significant gaps in technology and skills necessary for OSC implementation. There were notable technological gaps, but these could be addressed through financial support and increased investment in technical training and infrastructure (Datta et al., 2023; Ginigaddara et al., 2023). The development of OSC skills and the incorporation of advanced building technologies are underway, although they are not yet widespread (Ginigaddara et al., 2023). Overall, while Bangladesh's construction sector showed financial readiness for modern construction methods, technical readiness remained a challenge. Addressing these technical gaps through education, training and strategic partnerships was crucial for successfully adopting OSC in the country. The analysis indicated

that the construction industry in Bangladesh lacked adequate skills for implementing OSC. Most participants agreed that the necessary skills were insufficient. The main reasons cited include limited availability of advanced training, a lack of awareness and high initial costs associated with OSC technology. Despite these challenges, there was a consensus that skills could be developed through targeted training and education. Participants suggested partnerships between the government, educational institutions and industry players to facilitate the acquisition of necessary skills. This approach could help bridge the gap and make OSC a viable and efficient option in Bangladesh's construction sector.

The main impediments to applying off-site construction in Bangladesh

The analysis of the participants' insight highlighted several impediments to the adoption of OSC in Bangladesh. There was a significant lack of awareness and understanding of OSC among stakeholders, including policymakers, which hindered acceptance and implementation. Furthermore, the existing infrastructure, particularly transportation networks and supply chain management systems, was inadequate for supporting OSC. This included challenges related to the transportation of prefabricated components and the sourcing of materials. Most participants stated that regulatory frameworks were not well-suited to OSC, creating legal and procedural hurdles. Additionally, the high initial costs and limited access to financing posed significant challenges. Additionally, traditional building practices were deeply ingrained in society, resulting in their resistance to adopting new methods. This was compounded by concerns about the aesthetic and architectural diversity of OSC projects. A lack of collaboration between government, industry and educational institutions limited the R&D efforts necessary for optimising OSC techniques for the local context.

Improvement Strategies for the Implementation of Off-Site Construction

Participants were asked about the important elements that could improve the successful implementation of OSC in Bangladesh during the interview. This question was based on their experiences in the construction industry over several years. Table 3 presents a summary of the views of each participant in the interview session.

Table 3. The analysis of the views of each participant from the interview session

	Components	P1	P2	P3	P4	P5	P6	P7	P8	P9
1	Education and training for industry stakeholders	/	/	/	/	/	/	/	/	/
2	Supportive government policies and incentives	/	/	/	/	/	/	/	/	/
3	Investment in transportation infrastructure	/	/	/	/	/	/	/	/	/
4	Building local capacity for OSC manufacturing	/			/	/		/		
5	Encourage innovation and research in OSC	/	/		/	/	/	/	/	/
6	Develop risk management strategies and insurance solutions	/	/	/	/	/	/	/	/	/
7	Streamlined environmental clearance for OSC	/			/	/			/	/
8	Availability of raw materials for OSC production	/		/	/	/	/	/	/	/
9	Training initiatives for OSC skills development	/	/	/	/	/	/	/	/	/

The interview responses regarding improvement strategies for implementing OSC in Bangladesh highlighted several critical areas that required attention to facilitate the adoption of this innovative construction method. The consensus among participants emphasised the necessity of education and training for industry stakeholders, supportive government policies, investment in transportation infrastructure and the development of local manufacturing capacity for OSC products.

Firstly, the need for comprehensive education and training was paramount, as participants noted that a lack of understanding and skills among construction workers, engineers and architects had hindered the effective implementation of OSC. This aligned with findings from Assaad et al. (2022b), who stressed the importance of prioritising training to equip the workforce with the necessary skills for OSC. Furthermore, integrating OSC technologies required a well-informed workforce capable of managing prefabrication processes and modular assembly (Pan, Gibb and Dainty, 2012). Supportive government policies and incentives were also identified as crucial for promoting OSC. Participants emphasised that financial incentives, regulatory support and simplified approval processes could significantly alleviate the financial burden

on businesses investing in OSC technologies. This perspective was supported by Gan, Chang and Wen (2018), who argued that government regulations played a vital role in creating an environment conducive to innovation and adopting new construction methods. The implementation of such policies can help mitigate the initial costs associated with OSC, which are often perceived as a barrier to its adoption.

Investment in transportation infrastructure was highlighted as another critical factor. Therefore, improved logistics and transportation networks are essential for ensuring the timely delivery of prefabricated components, which is crucial for maintaining project schedules and budgets. This aligned with the findings of Almashaqbeh and El-Rayes (2022), who emphasised the importance of efficient transportation systems in minimising delays and costs associated with OSC projects. Additionally, participants noted the importance of building local capacity for OSC manufacturing. While some acknowledged the high initial costs and limited availability of precast products in Bangladesh, they recognised that developing local manufacturing capabilities could enhance the implementation of OSC. This was consistent with the findings of Abdul Hamid (2019), who suggested that local manufacturing can significantly impact the sustainability and efficiency of construction practices. Encouraging innovation and research in OSC was also deemed essential. Participants believed fostering a culture of innovation could attract stakeholder interest and lead to advancements in construction quality, efficiency and sustainability. This was supported by the literature, which indicates that promoting R&D in OSC could create cutting-edge materials and methods that enhance overall project outcomes (Musa et al., 2018).

Lastly, the need for effective risk management strategies and streamlined environmental clearance processes was emphasised. Participants agreed that addressing potential risks associated with OSC through proactive management and tailored insurance solutions could facilitate its adoption. This aligned with the findings of Hwang, Shan and Looi (2018), who discussed the importance of risk mitigation strategies in successfully implementing prefabricated construction methods. In summary, the insights gathered from the interviews underscore the multifaceted approach required to enhance the implementation of OSC in Bangladesh. By focusing on education, supportive policies, infrastructure investment, local manufacturing, innovation, risk management and environmental considerations, stakeholders could create a more conducive environment for the adoption of OSC practices.

CONCLUSIONS

This study provided valuable insights into the current state of OSC adoption in Bangladesh by highlighting key barriers and potential strategies for improvement. The findings revealed a complex landscape where financial readiness and significant technical and infrastructural challenges existed. The primary barriers identified included lack of awareness and understanding among stakeholders, insufficient government support and incentives, inadequate skills and training in the workforce, limited transportation infrastructure and logistics capabilities, high initial costs and limited access to financing, resistance to change from traditional construction methods, lack of local manufacturing capacity for OSC components and insufficient collaboration between industry, government and educational institutions.

To address these challenges and promote the adoption of OSC in Bangladesh, several key strategies have emerged:

1. Comprehensive education and training programmes for all stakeholders.
2. Development of supportive government policies and financial incentives.
3. Investment in transportation infrastructure to facilitate logistics.
4. Encouragement of local manufacturing capabilities for OSC components.
5. Promotion of research and innovation in OSC technologies.
6. Implementation of effective risk management strategies.
7. Streamlining of environmental clearance processes for OSC projects.

The successful implementation of these strategies requires a coordinated effort from all stakeholders in the construction industry, including government bodies, educational institutions and private sector companies. By addressing the identified barriers and leveraging the country's financial readiness, Bangladesh has the potential to significantly enhance its construction sector through the adoption of OSC methods.

Future research should focus on developing detailed implementation plans for the proposed strategies, quantifying the potential economic and environmental benefits of OSC adoption in Bangladesh and exploring innovative financing models to support the transition to modern construction methods. Additionally, case studies of successful OSC projects in similar developing countries could provide valuable lessons and best practices for Bangladesh's construction industry. In conclusion, though Bangladesh faces significant challenges in adopting OSC, there is a clear path forward. With

targeted interventions and collaborative efforts, the country can harness the benefits of OSC to improve construction efficiency, quality and sustainability, ultimately contributing to its broader economic development goals.

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REFERENCES

Abd Razak, M.I., Khoiry, M.A., Badaruzzaman, W.H.W. and Hussain, A.H. (2022). DfMA for a better industrialised building system. *Buildings*, 12(6): 794. https://doi.org/10.3390/BUILDINGS12060794

Abdul Hamid, R.Y.A.R. (2019). An integrated approach for sustainability in the application of Industrialised Building System (IBS). *International Journal of GEOMATE*, 17(61): 115–121. https://doi.org/10.21660/2019.61.4810

Almashaqbeh, M. and El-Rayes, K. (2022). Minimizing transportation cost of prefabricated modules in modular construction projects. *Engineering, Construction and Architectural Management*, 29(10): 3847–3867. https://doi.org/10.1108/ECAM-11-2020-0969

Arif, M., Bendi, D., Sawhney, A. and Iyer, K.C. (2012a). State of offsite construction in India-drivers and barriers. *Journal of Physics: Conference Series*, 364: 012109. https://doi.org/10.1088/1742-6596/364/1/012109

Arif, M., Bendi, D., Toma-Sabbagh, T. and Sutrisna, M. (2012b). Construction waste management in India: An exploratory study. *Construction Innovation*, 12(2): 133–155. https://doi.org/10.1108/14714171211215912/FULL/XML

Assaad, R.H., El-adaway, I.H., Hastak, M. and Needy, K.L. (2022a). Key factors affecting labor productivity in offsite construction projects. *Journal of Construction Engineering and Management*, 149(1): 04022158. https://doi.org/10.1061/JCEMD4.COENG-12654

_____. (2022b). The impact of offsite construction on the workforce: Required skillset and prioritization of training needs. *Journal of Construction Engineering and Management*, 148(7): 04022056. https://doi.org/10.1061/(ASCE)CO.1943-7862.0002314

Beulah, F. (2022). Challenges faced in prefabrication or modular construction. *International Journal for Research in Applied Science and Engineering Technology*, 10(1): 168–178. https://doi.org/10.22214/ijraset.2022.39789

Blismas, N. and Wakefield, R. (2009). Drivers, constraints and the future of offsite manufacture in Australia. *Construction Innovation*, 9(1): 72–83. https://doi.org/10.1108/14714170910931552

Charlson, J. and Dimka, N. (2021). Design, manufacture and construct procurement model for volumetric offsite manufacturing in the UK housing sector. *Construction Innovation*, 21(4): 800–817. https://doi.org/10.1108/ci-10-2019-0108

Chowdhury, R. (2022). Adoption of prefabricated construction in Bangladesh: Prospects adoption of prefabricated construction in Bangladesh. Paper presented at the 3rd International Conference on Research and Innovation in Civil Engineering. Chattogram, Bangladesh, 5–6 January.

Datta, S.D. and Assafi, M.N. (2022). Offsite construction in Bangladesh: Barriers and future. Paper presented at the 6th International Conference on Civil Engineering for Sustainable Development (ICCESD 2022). Khulna, Bangladesh, 10–12 February.

Datta, S.D., Sobuz, Md.H.R., Nafe Assafi, M., Sutan, N.M., Islam, M.N., Mannan, M.B., Akid, A.S.M. and Hasan, N.M.S. (2023). Critical project management success factors analysis for the construction industry of Bangladesh. *International Journal of Building Pathology and Adaptation*, 43(3): 482–511. https://doi.org/10.1108/ijbpa-01-2022-0006

Gan, X., Chang, R. and Wen, T. (2018). Overcoming barriers to off-site construction through engaging stakeholders: A two-mode social network analysis. *Journal of Cleaner Production*, 201: 735–747. https://doi.org/10.1016/j.jclepro.2018.07.299

Gan, X., Chang, R., Zuo, J., Wen, T. and Zillante, G. (2018). Barriers to the transition towards off-site construction in China: An interpretive structural modeling approach. *Journal of Cleaner Production*, 201: 8–18. https://doi.org/10.1016/j.jclepro.2018.06.184

Ginigaddara, B., Perera, S., Feng, Y., Rahnamayiezekavat, P. and Thomson, R. (2023). Development of offsite construction skill profile prediction models using mixed-effect regression analysis. *Construction Management and Economics*, 41(10): 820–839. https://doi.org/10.1080/01446193.2023.2209667

Hwang, B.-G., Shan, M. and Looi, K.-Y. (2018). Key constraints and mitigation strategies for prefabricated prefinished volumetric construction. *Journal of Cleaner Production*, 183: 183–193. https://doi.org/10.1016/j.jclepro.2018.02.136

Jaillon, L. and Poon, C.S. (2010). Design issues of using prefabrication in Hong Kong building construction. *Construction Management and Economics*, 28(10): 1025–1042. https://doi.org/10.1080/01446193.2010.498481

Jalil, M.A. and Mia, M.T. (2021). The role of Padma Multipurpose Bridge in the national sustainable development in Bangladesh. *Journal of Asian and African Social Science and Humanities,* 7(1): 38–53.

Jang, J., Ahn, S., Cha, S.H., Cho, K., Koo, C. and Kim, T.W. (2021). Toward productivity in future construction: Mapping knowledge and finding insights for achieving successful offsite construction projects. *Journal of Computational Design and Engineering*, 8(1): 1–14. https://doi.org/10.1093/jcde/qwaa071

Jin, R., Gao, S., Cheshmehzangi, A. and Aboagye-Nimo, E. (2018). A holistic review of off-site construction literature published between 2008 and 2018. *Journal of Cleaner Production*, 202: 1202–1219. https://doi.org/10.1016/j.jclepro.2018.08.195

Jin, R., Hong, J. and Zuo, J. (2020). Environmental performance of off-site constructed facilities: A critical review. *Energy and Buildings*, 207: 109567. https://doi.org/10.1016/J.ENBUILD.2019.109567

Jung, S. and Yu, J. (2022). Design for manufacturing and assembly (DfMA) checklists for off-site construction (OSC) projects. *Sustainability*, 14(19): 11988. https://doi.org/10.3390/su141911988

Kurpinska, M., Grzyl, B. and Kristowski, A. (2019). Cost analysis of prefabricated elements of the ordinary and lightweight concrete walls in residential construction. *Materials,* 12(21): 3629. https://doi.org/10.3390/MA12213629

Li, Z., Zhang, S. and Meng, Q. (2021). Modeling adoption behavior of prefabricated building with multiagent interaction: System dynamics analysis based on data of Jiangsu Province. *Computational Intelligence and Neuroscience*, 1: 3652706. https://doi.org/10.1155/2021/3652706

Lu, W., Lee, W.M.W., Xue, F. and Xu, J. (2021). Revisiting the effects of prefabrication on construction waste minimization: A quantitative study using bigger data. *Resources, Conservation and Recycling*, 170: 105579. https://doi.org/10.1016/j.resconrec.2021.105579

Mao, C., Shen, Q., Asce, M., Pan, W. and Ye, K. (2013). Major barriers to off-site construction: The developer's perspective in China. *Journal of Management in Engineering*, 31(3): 04014043. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000246

Mohammad, M.F., Baharin, A.S., Musa, M.F. and Yusof, M.R. (2016). The potential application of IBS modular system in the construction of housing scheme in Malaysia. *Procedia - Social and Behavioral Sciences*, 222: 75–82. https://doi.org/10.1016/J.SBSPRO.2016.05.189

Muhammad, W.M.N.W., Azman, M.A., Othman, M.K.F., Hadi, N.A., Sahimi, S.N.S. and Mohammad, M.F. (2016). The insight of industrialised building system (IBS) by Bumiputera construction players. *MATEC Web of Conferences*, 47: 04013. https://doi.org/10.1051/matecconf/20164704013

Musa, M.F., Mohammad, M.F., Mahbub, R. and Yusof, M.R. (2018). Adopting modular construction in the Malaysian construction industry. *Asian Journal of Environment-Behaviour Studies*, 3(10): 1–9. https://doi.org/10.21834/AJE-BS.V3I10.307

Pan, W., Gibb, A.G.F. and Dainty, A.R.J. (2012). Strategies for integrating the use of off-site production technologies in house building. *Journal of Construction Engineering and Management*, 138(11): 1331–1340. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000544

Rahman, M.M. and Asce, M. (2013). Barriers of implementing modern methods of construction. *Journal of Management in Engineering*, 30(1): 69–77. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000173

Razkenari, M., Fenner, A., Shojaei, A., Hakim, H. and Kibert, C. (2020). Perceptions of offsite construction in the United States: An investigation of current practices. *Journal of Building Engineering*, 29: 101138. https://doi.org/10.1016/j.jobe.2019.101138

Salama, T., Moselhi, O. and Al-Hussein, M. (2021). Overview of the characteristics of the modular industry and barriers to its increased market share. *International Journal of Industrialized Construction*, 2(1): 30–53. https://doi.org/10.29173/IJIC249

Shahzad, W.M., Rajakannu, G. and Kordestani Ghalenoei, N. (2022). Potential of modular offsite construction for emergency situations: A New Zealand study. *Buildings 2022*, 12(11): 1970. https://doi.org/10.3390/BUILDINGS12111970

Sharma, G. (2017). Pros and cons of different sampling techniques. *International Journal of Applied Research*, 3(7): 749–752.

Song, Y., Wang, J., Guo, F., Lu, J. and Liu, S. (2021). Research on supplier selection of prefabricated building elements from the perspective of sustainable development. *Sustainability*, 13(11): 6080. https://doi.org/10.3390/su13116080

Sourav, M.M.I., Afnanin, S. and Islam, M.R. (2023). Impact of Padma Bridge on transportation system: A case study for Barisal Division. *Journal of Engineering and Applied Science*, 70(1): 1–14. https://doi.org/10.1186/S44147-023-00299-1/TABLES/4

Sutrisna, M., Cooper-Cooke, B., Goulding, J. and Ezcan, V. (2019). Investigating the cost of offsite construction housing in Western Australia. *International Journal of Housing Markets and Analysis*, 12(1): 1753–8270. https://doi.org/10.1108/IJHMA-05-2018-0029

Sutrisna, M., Ramnauth, V. and Zaman, A. (2022). Towards adopting off-site construction in housing sectors as a potential source of competitive advantage for builders. *Architectural Engineering and Design Management*, 18(3): 165–183. https://doi.org/10.1080/17452007.2020.1807306

World Bank Group (2021). *Country Private Sector Diagnostic: Creating Markets in Bangladesh – Unleashing the Private Sector to Sustain Development Success.* Washington, DC: World Bank Group.

Zhang, H. and Yu, L. (2021). Resilience-cost tradeoff supply chain planning for the prefabricated construction project. *Journal of Civil Engineering and Management*, 27(1): 45–59. https://doi.org/10.3846/JCEM.2021.14114

Zhang, X., Skitmore, M. and Peng, Y. (2014). Exploring the challenges to industrialized residential building in China. *Habitat International*, 41: 176–184. https://doi.org/10.1016/j.habitatint.2013.08.005