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TOWARDS SUCCESSFUL IMPLEMENTATION OF OFFSITE CONSTRUCTION IN SRI LANKA: BARRIERS AND STRATEGIES

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ABSTRACT

The construction industry has significantly progressed by incorporating modern construction technologies. Offsite building is growing in popularity, yet it continues to face resistance from the built environment market and the construction industry. Offsite construction (OSC) is gaining recognition globally as a sustainable, efficient, and innovative alternative to traditional construction methods. In Sri Lanka, despite the evident benefits but OSC adoption remains limited due to several barriers. This research aims to investigate and identify strategies to overcome the barriers that hinder the successful implementation of OSC in building projects in Sri Lanka. Accordingly, the literature review highlighted the feasibility of OSC for the Sri Lankan construction industry and the advantages and barriers of OSC in the Sri Lankan context. Moreover, semi-structured expert interviews were conducted with 10 experts to gather data, and thematic analysis was used to analyze the collected interview data. Findings reveal that the primary barriers include high initial capital costs, lack of skilled labour, insufficient governmental support, limited public awareness, and a reliance on conventional construction practices. Additionally, logistical challenges, such as transporting prefabricated components, and the absence of standardized design codes further constrain OSC implementation. Despite these obstacles, the study emphasizes the transformative 5 potential strategies proposed for promoting the adoption of OSC in building projects in Sri Lanka. This strategy strives to empower Sri Lanka towards a more innovative, productive, and sustainable construction industry

Keywords: *Construction Industry; Offsite construction (OSC); Strategy*

1. INTRODUCTION

The rapid development of the construction industry has brought about critical issues such as resource depletion, environmental pollution, and ecological damage (Liu and Abidin, 2024). In the Sri Lankan context, construction material wastage is notably high during both construction and demolition processes (Bimsara et al., 2024). Given the significant

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environmental pressures faced by the industry, there is an increasing urgency to adopt more eco-friendly construction methods (Liu & Abidin, 2024).

The construction industry has made significant progress with the incorporation of modern construction technologies (Wasana, et al., 2019). Off-site building can be thought of as a viable solution for the challenges connected to the conventional construction techniques currently employed in the construction industry (Wasana et al., 2019). The offsite building is becoming more popular, but it still faces resistance from the built environment market and the construction industry (Razkenari et al., 2020).

Also, the construction industry is competitive, with cost as the main focus for contractors. To stay relevant, they must continually reduce project costs while maintaining quality. (Sandamini & Waidyasekara, 2022). Jayasena et al. (2023) stated the adoption of OSC techniques, such as prefabrication, to improve efficiency and reduce construction waste. Prefabricated construction provides a new direction for transforming and upgrading the construction industry (Jin et al., 2018). It is stated that the industry's performance might be improved via collaboration among all the stakeholders and the use of new construction building materials, such as off-site manufacturing, to reduce construction costs (Dharmendra & Thusyanthan, 2021)

Sanjeepan (2017) suggests that Sri Lanka's construction industry should focus on off-site construction methods to attain these advantages. In Sri Lanka, the construction industry mainly uses traditional onsite methods, but recent advancements in OSC have led to more case studies and research. Still, there is a lack of review papers examining various aspects of offsite buildings (Razkenari et al., 2020). Sri Lanka is slow to adopt prefabricated construction due to inherent barriers. As a developing economy, Sri Lanka significantly lags in adopting prefabricated construction technologies compared to developed and industrialized economies (Jayawardana et al., 2023). OSC offers significant benefits for Sri Lanka's construction industry, but low adoption due to persistent barriers. Investigating these barriers and developing effective strategies is essential to unlock OSC's potential and guide industry growth. Therefore, this research aims to identify strategies to overcome the barriers that hinder the successful implementation of OSC in building projects in Sri Lanka. Firstly, the research identified the feasibility and suitability of OSC in the Sri Lankan context. Secondly, it examined the potential benefits associated with the implementation of OSC in local building projects. Thirdly, the study investigated the key barriers hindering the adoption of OSC within the construction industry. Ultimately, the research will propose strategies for promoting the adoption of OSC in building projects in Sri Lanka.

2. LITERATURE REVIEW

2.1 OVERVIEW OF OSC

OSC consists of creating building components and modules in a controlled environment, transporting them to the construction site, and assembling or installing them on site (Assaad et al., 2022). The OSC method is classified into volumetric systems, panel systems, hybrid systems, and sub-assemblies and components (Gunawardena et al., 2016; Sanjeepan, 2017)

OSC presents a compelling opportunity for the construction industry in Sri Lanka, as it enhances economic feasibility and overall efficiency (Gunarathne et al., 2023). Many

government reports emphasize the importance of addressing issues within the traditional construction industry. They propose adopting innovations based on a modern and sophisticated technique known as OSC. This approach is seen as a revolutionary and sustainable solution to the challenges the industry faces (Abanda et al., 2017). According to Jayasena et al. (2023) findings OSC technique is one of the suitable strategies to overcome challenges in construction innovation projects in Sri Lanka. These methods can significantly enhance the efficiency of the construction process while minimizing waste, thereby addressing key challenges in the industry (Jayasena et al., 2023).

2.2 BENEFITS OF OSC

OSC techniques have emerged as a promising solution to address many challenges in the Sri Lankan construction industry. These techniques offer numerous advantages, ranging from cost savings to environmental benefits.

Sanjeepan (2017) highlights that OSC provides multiple benefits, including cost reductions, increased productivity, enhanced quality control, and a lower environmental footprint. Similarly, Rahimian et al. (2017) emphasize that offsite manufacturing conducted in a controlled environment contributes to faster construction speeds, improved product quality, reduced costs, and decreased on-site labour requirements. The advantage of faster construction is particularly significant. According to Hong et al. (2018), volumetric construction techniques can improve construction schedule efficiency by up to 50%, a remarkable contribution to addressing delays commonly observed in traditional construction. Worker safety is another critical area where OSC demonstrates significant impact. Offsite prefabrication can reduce the occurrence of safety incidents by 80% to 85%, thereby minimizing risks and enhancing worker safety (Navaratnam, 2022). The factory-centric nature of volumetric construction naturally reduces on-site hazards, as noted by Balasbaneh and Ramli (2020) who emphasize the importance of safety in construction projects.

The quality of final construction products is also notably improved through OSM. Gan et al. (2018) and Peltokorpi et al. (2018) support the claim that OSM not only speeds up construction but also improves the quality of the final product while substantially reducing construction costs. Gan et al. (2018) add additional importance to the benefits of OSC, emphasizing that it not only expedites the construction process but also improves the overall standard of the completed work. This is a critical component since the long-term operation and durability of structures are dependent upon the level of quality of the construction process. In the long run, projects involving essential infrastructure and urban growth may become more financially feasible and environmentally friendly as building prices decrease (Peltokorpi et al., 2018).

Environmentally, OSC aligns well with Sri Lanka's sustainability goals. According to Sandamini and Waidyasekara (2022) and Razkenari et al. (2020), OSC has environmental benefits that are under the country's sustainability targets. These advantages include decreased waste, pollution, and depletion of resources. They mark a substantial advancement in Sri Lanka's construction industry's transition to a greener and more sustainable one (Sandamini & Waidyasekara, 2022).

2.3 BARRIERS OF OSC

Sanjeepan (2017) stated that given issues with industry capacity, public perception, and attitude, as well as off-site construction's higher cost compared to conventional building, off-site construction has seen little usage within the construction industry.

Gan et al. (2018) highlight inadequate policies and regulations, lacking knowledge and skills, dominated traditional project approach, and poor standardization as the most pressing problems. According to Uthpala and Ramachandra (2015), the cost of OSC is a major barrier, with OSC projects costing 7% to 10% more than conventional building projects due to the speedier construction and higher-quality off-site construction. Cost factors for prefabricated buildings are complex, involving technology, policy, market conditions, materials, and management. A major challenge is high capital costs, often resulting from poor coordination, weak supply chain integration, and complicated connections (Liu & Abidin, 2024).

According to the literature review findings, barriers to OSC in the Sri Lankan context are given in Table 1.

Table 1: Identified barriers to OSC in Sri Lanka from literature review

Barriers	Source
Lack of experienced collaboration groups	3,6,13
Lack of manufacturers and suppliers of prefabricated components	1,3,6
Transportation of prefabricated elements and access to the building site	2,3,13
Lack of experienced contractors on prefabrication	6
Poor integration for the supply chain	6
Longer lead-in time for OSC components	4,6
Low productivity	1
High-skill demands for labour	3,7,6
Increase in complexity for maintenance	1,6
High initial & capital cost	3,6,9,10,11,12,13
Longer capital payback period	3,6,9,12
Increased cost due to higher quality/rapid construction	3
Lack of design codes and standards for prefabricated components	4,8,7,6,12
Lack of governmental regulations and incentives	8,6
Lack of technologies and testing institute to prefabricated components	2
The owner’s negative perception	1,2,3,4,6
Lack of awareness of prefabrication by the market and public	2,3,11
Dependence of traditional construction method	1,2,3,5,7,12
Poor quality impression	1,2,7,6
Lack of confidence of the industry in offsite production	6,13
Project planning and coordination	1,3,4,9
Uncertainty of market demand	1

	Barriers		Source
1.	(Jayasena et al., 2023)	8.	(Blismas et al., 2005)
2.	(Kamar et al., 2009)	9.	(Hwang et al., 2018)
3.	(Pan & Sidwell, 2011)	10.	(Razkenari et al., 2020)
4.	(Sanjeepan, 2017)	11.	(Rahimian et al., 2017)
5.	(Pan et al., 2008)	12.	(Gan et al., 2018)
6.	(Zhai et al., 2014)	13.	(Dharmendra & Thusyanthan, 2021)
7.	(Mao et al., 2015)		

3. METHODOLOGY

This study adopts a qualitative, inductive approach to investigate the strategies to overcome the barriers that hinder the successful implementation of OSC in building projects in Sri Lanka. Qualitative research explores the meanings and perceptions of individuals or groups by gathering and analyzing textual data through methods such as surveys, interviews, focus groups, and observations (Borrego et al., 2009).

3.1 DATA COLLECTION PROCESS

Data collection integrates a systematic literature review and semi-structured interviews. Interviews are considered one of the best selection techniques as its goes up to the depth of opinion of the interviewees (Kallio et al., 2016). This will involve conducting semi-structured interviews with diverse stakeholders involved in building projects in Sri Lanka, such as architects, engineers, contractors, and workers.

3.2 DATA ANALYSIS PROCESS

Semi-structured interviews were chosen as they allow flexibility to explore participants' experiences in-depth while maintaining consistency across interviews (Kallio et al., 2016). This approach is common in qualitative research where participants are selected based on their expertise and relevance to the study (Etikan, 2016). A semi-structured interview was conducted with ten interviewees in the local construction industry. A sample of 10 participants was adequate to reach data saturation, ensuring rich and relevant insights without unnecessary repetition (Guest et al., 2006). The interview was designed to investigate local practices, ensuring that the responses collected would offer valuable insights into the local construction industry. Interview responses data were analyzed using thematic analysis. A qualitative data analysis method involves identifying recurring ideas in a data set. Typically, a researcher conducting thematic analysis will work with interview data and attempt to derive themes inductively (Jason & Glenwick, 2015).

3.2.1 Expertise Core Data Analysis

Table 2 represents the demographic data analysis of the semi-structured interviews.

Table 2: Demographic data analysis

Profession	No. of Interviewees	Years of experience
Senior Project Manager	4	More than 15 years
Site Manager	3	More than 12 years
Senior Quantity Surveyor	1	More than 15 years

Profession	No. of Interviewees	Years of experience
Senior Architect	1	10 Years
Civil Engineer	1	15 Years

4. RESULTS AND DISCUSSION

A literature review was conducted to identify the potential advantages and barriers of off-site construction. Semi-structured interviews were conducted with ten experts from the Sri Lankan construction industry to further explore the benefits and challenges of OSC, while also identifying practical strategies to overcome the barriers associated with its implementation. Responses were provided to address the needs of the local construction context, emphasizing their relevance to the practice of off-site construction in the Sri Lankan context.

4.1 RESPONSES OF THE INTERVIEWEES FOR THE ADVANTAGES OF OSC

From the insights gathered in the interviews and the literature review, the compelling advantages of OSC are thoroughly explored. According to semi-structured interview findings, the advantages of OSC data analysis are given in Table 3.

Table 3: Identified Advantages of OSC

	Identified benefits of OSC	Literature review	Interview responses
1	Time saving (Speed & Efficiency)	✓	10
2	Reduced wastage	✓	7
3	Cost Reduction	✓	6
4	Quality Improvement	✓	4
5	Improve health and safety	✓	4
6	Environmental Benefits	✓	4
7	Addressing Shortage of Skills	✓	2
8	Productivity Improvement	✓	1

The majority of interviewees, approaching 100%, agreed that offsite building excels at saving time on construction projects. Interviewees explored this is achieved by manufacturing components in controlled environments and assembling them on-site, ensuring adherence to schedules and leveraging economies of scale. Cost reduction is another notable advantage, primarily driven by minimized labour requirements, reduced material waste, and the efficiency of precast construction, which offers up to 40% savings compared to traditional methods.

OSC also promotes quality improvement through prefabrication, standardized processes, and rigorous inspection and testing, ensuring consistency across projects. The approach addresses the shortage of skilled labour by shifting much of the work to controlled environments, reducing reliance on on-site labour. Safety is significantly enhanced, as the controlled production environment minimizes accident risks compared to traditional on-site construction.

Environmental benefits are also prominent, including reduced waste, noise pollution, and a lower carbon footprint. Components manufactured with precision eliminate excessive material usage, while resource efficiency conserves energy and materials. These advantages position OSC as a transformative approach for improving efficiency, sustainability, and safety in the construction industry while addressing key challenges.

4.2 OPPORTUNITIES AND CHALLENGES IN IMPLEMENTING RECYCLING AND REUSE PROGRAMMES IN SRI LANKA'S CONSTRUCTION INDUSTRY

The findings from the interviews and literature review reveal several significant barriers to the adoption of off-site construction. Interview responses indicated that the most critical challenges are the lack of awareness and understanding of off-site construction benefits and the high initial and capital costs involved. Additionally, 60% of respondents highlighted the lack of confidence and experience among contractors and designers, alongside a notable gap in skilled labour availability. Financial concerns, such as the extended capital payback period, were noted by 40% of participants, further emphasizing the economic challenges faced by stakeholders. According to the semi-structured interview findings, the barriers of OSC data analysis are given in Table 4.

Table 4: Identified barriers for OSC

	Identified barriers for OSC	Literature review	Interview responses
1	Lack of awareness and understanding	✓	10
2	High initial and capital cost	✓	10
3	Limited availability of specialized equipment		6
4	Lack of confidence	✓	6
5	Lack of experienced contractors	✓	6
6	Lack of experienced design consultancy and designers		6
7	High skill demands for labor	✓	6
8	Lack of experienced collaboration groups	✓	4
9	Longer capital payback period		4
10	Lack of practice and experience in local projects		3
11	Lack of technologies and testing	✓	3
12	Transportation issues	✓	3
13	Dependence of traditional construction method	✓	3
14	Project scheduling issues		3
15	Lack of governmental regulations and incentives	✓	2
16	Lack of local Research and Development institutes and services		2
17	Uncertainty of market demand	✓	2
18	Lack of manufacturers & suppliers	✓	2
19	Unpredictable planning decisions		2
20	The fragmented nature of the construction industry		2

	Identified barriers for OSC	Literature review	Interview responses
21	Lack of design codes and standards	✓	2
22	Poor quality impression	✓	2
23	Off-site construction techniques limit design options		2
24	Project planning and coordination	✓	1
25	Poor integration for the supply chain	✓	1
26	Additional maintenance cost for heavy machinery		1
27	Inability to make changes in the field		1
28	Risk management and liability		1

These findings align with literature findings, identifying key systemic barriers such as the lack of design codes and standards for prefabricated components, insufficient governmental regulations and incentives, and the negative perceptions of project owners. It also underscores a persistent dependence on traditional construction methods, which hinder the industry's transition to modern practices. Additional challenges include supply chain inefficiencies, logistical constraints in transporting prefabricated components, and high technological costs.

These results highlight the interconnected nature of the barriers, where knowledge gaps, financial limitations, regulatory shortcomings, and skill deficiencies collectively impede the adoption of off-site construction. Addressing these challenges requires a multi-faceted approach, as discussed in the literature, with particular attention to overcoming the barriers identified in the interviews.

Taking these complex issues into consideration is essential to coordinating an effective shift to OSC techniques in the Sri Lankan setting. Taking a closer look at the money side of things, careful planning is needed to reduce the large in advance and capital costs of offsite building and create an environment that makes adoption easier. In order to guarantee compliance in the construction sector and to offer a strong basis for standardized procedures, regulatory frameworks must be developed and refined at the same time.

Essentially, this all-encompassing approach highlights the need for a holistic strategy while acknowledging the interconnectedness of these issues. Sri Lanka can only effectively navigate and embrace the transformative potential of OSC methodologies by making a concentrated effort to address the financial, regulatory, perceptual, skill-related, logistical, and technological aspects.

4.3 STRATEGIES FOR PROMOTING OSC IN SRI LANKAN BUILDING PROJECTS

The adoption of OSC in Sri Lanka faces several barriers and to overcome these obstacles, targeted strategies are essential. Addressing these barriers with tailored strategies will pave the way for the growth of OSC in Sri Lanka's building sector. The majority of interviewees identified several important strategies for the successful implementation of off-site construction projects in Sri Lanka. These include awareness and education, development and research, public acceptance and perception, financial incentives, and

projects for demonstration. According to the semi-structured interview findings, proposed strategies and strategy incentives to overcome the barriers are given in Table 5.

Table 5: Proposed strategies

Proposed strategy	Strategy incentives	Barriers
Awareness and Education	Conduct training, workshops, and awareness campaigns targeting industry stakeholders	Lack of awareness[1], lack of confidence[4], lack of experienced contractors[5], high skill demands[7], lack of collaboration groups[8], traditional methods[13], project, Project scheduling issues[14] coordination[24], risk management[28], Fragmented industry[20], supply chain issues[25], planning unpredictability[19]
Development and Research	Invest in local Research and Development, establish institutes, and innovate with new technologies	Limited equipment[3], lack of design consultancy[6], lack of prefab testing institutes[11], transportation issues[12], lack of local Research and Development[16], lack of manufacturers and suppliers[18], design codes[21], field changes[27], limit design options[23]
Public Acceptance and Perception	Promote successful projects to gain public trust and improve market acceptance	Uncertainty in market demand[17], poor quality impressions[22]
Financial Incentives	Provide subsidies, tax benefits, grants, and low-interest loans to reduce financial burdens	High initial costs[2], longer payback periods[9], lack of regulations[15], additional machinery maintenance costs[26]
Projects for Demonstration	Encourage pilot projects to build local expertise	Lack of practice and experience in local projects[10]

According to the insights from interviewees, institutions of higher learning should integrate off-site construction methods into their courses. Research and development initiatives should allocate funds to develop locally adapted off-site construction technologies and foster collaborations between academics, research facilities, and the construction sector. To address misconceptions and highlight the advantages of off-site construction, such as economic and environmental benefits, public awareness campaigns should be launched to build trust within communities. Financial incentives like tax breaks, grants, and specialized loans should be provided to developers and contractors adopting off-site methods, supported by partnerships with financial institutions. Additionally, successful off-site construction projects should be showcased as prototypes to demonstrate the method's viability and benefits, attracting stakeholders and emphasizing cost reduction, enhanced quality, and decreased construction time.

5. CONCLUSIONS

This study provides critical insights into the implementation of OSC in Sri Lanka by highlighting both common global barriers and unique local challenges. While many identified barriers, such as high initial costs, lack of skilled labour, and inadequate regulatory support, mirror those found in international contexts, the Sri Lankan setting is further constrained by deeply rooted preferences for traditional construction methods and limited awareness among stakeholders. These context-specific challenges stem from a combination of cultural resistance, insufficient local manufacturing capabilities, and policy gaps.

Despite these barriers, the study also reveals key enablers of OSC adoption in Sri Lanka, including its potential to reduce construction time, improve safety, and support environmental sustainability, benefits consistent with global findings. However, the success of OSC in Sri Lanka depends heavily on strategic, locally adapted interventions that build confidence and capabilities within the industry.

The study contributes to the body of knowledge by bridging global OSC discourse with the underexplored Sri Lankan context. It proposes a targeted framework of five practical strategies, awareness and education, research and development, public perception enhancement, financial incentives, and demonstration projects, tailored to Sri Lanka's socio-economic and industrial environment. These insights not only guide local practitioners and policymakers but also offer a reference model for other developing countries facing similar implementation challenges in modernizing their construction sectors

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