

CAN LEAN CONSTRUCTION IMPROVE SITE READINESS TO FACILITATE MODERN METHODS OF CONSTRUCTION INTEGRATION?

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ABSTRACT

The advantages of Modern Methods of Construction (MMC) are frequently compromised when on-site construction activities are not adequately prepared to deliver and integrate MMC components. This study investigates challenges encountered by both MMC organisations and on-site teams in coordinating MMC with traditional building practices. Employing a mixed-methods case study approach, the research comprises semi-structured interviews with representatives from MMC providers and construction companies, as well as systematic observations conducted during multiple site visits. The findings highlight significant challenges in reconciling the standardisation inherent in MMC processes with the adaptability expected of contractors on site. This often results in friction between production-focused perspectives and entrenched conventional approaches.

To address these issues, the study recommends fostering a culture that values innovation and cultivates trust in MMC solutions. Key strategies include encouraging early, proactive collaboration among design, manufacturing, and on-site stakeholders; adopting a focused quality mindset for on-site activities; and directly addressing concerns about increased on-site workload or approval delays. Supporting measures, such as targeted training initiatives, clear communication of programme expectations, and visible leadership endorsement of MMC adoption, are essential for dispelling misconceptions and creating an environment conducive to successful integration.

KEYWORDS

Modern Methods of Construction, Last Planner System, Just-In-Time, quality.

INTRODUCTION

Modern Methods of Construction (MMC) encompass a broad spectrum of offsite and onsite approaches and offer viable alternatives to conventional construction techniques. It has the potential to drive substantial improvements in productivity, efficiency, and quality across both the construction industry and the public sector (Mandala and Nayaka, 2025). According to Galster and Ok Lee (2021), there is a growing demand for housing in many cities across the world, and MMC is viewed as a necessary solution to address both speed of construction and affordability. MMC's ability to facilitate the rapid delivery of high-quality homes, when

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compared to conventional onsite construction techniques, enables faster construction timelines, which is particularly valuable in addressing the pressing issue of affordable housing supply (Sweeney, 2024). The efficiency and quality inherent in MMC processes can help meet growing societal demands for accessible and cost-effective housing solutions; MMC is not a panacea, but it could play a key role in addressing the housing crisis (Wallace et al., 2025). Outside of housing, MMC are increasingly being adopted across the wider construction sector and can contribute to the development of a more sustainable built environment, promote improved working conditions, and achieve greater productivity within construction activities (Galster and Ok Lee, 2021; Sweeney, 2024).

To support and guide the implementation of MMC, various national frameworks have been established. The National MMC Definition Frameworks (MHCLG, 2019; DHLGH, 2023) delineate seven distinct categories of MMC. Categories one through five focus on off-site manufacturing processes, while categories six and seven are concerned with enhancing productivity and process improvements on-site. This structured classification system provides a foundation for understanding and promoting the adoption of MMC across various stages and elements of the construction process.

Despite several Government and industry reports promoting MMC (Farmer, 2016; MHCLG, 2019; DHLGH, 2022), general adoption has been slow, with factors such as building failures, prejudice, economic barriers, a lack of performance data, and customer concerns all requiring to be addressed (Rahman, 2014; Rushton, 2022). Saad et al. (2025) suggest innovation is essential for the construction industry to effectively respond to emerging challenges and fulfil stakeholder expectations, especially with respect to the development of more sustainable facilities and infrastructure. However, Green (2022) warrants caution regarding the pursuit of productivity and innovation, suggesting strong and robust governance of materials and construction practices is required. Additionally, O'Hegarty et al. (2025) are sceptical about MMC's ability to deliver on its promises, and Saad et al. (2025) report that MMC is perceived as constrained by its historical failures, which currently outweigh its inherent advantages and potential.

With recent advancements in MMC production processes, innovation, and quality, it is evident that on-site preparation and readiness can be a weak point, thereby limiting the advantages that can accrue. Many publications focus on the benefits of MMC; however, there is a lack of discussion of the changes and mindset required for site processes to align and be 'ready' to integrate MMC. Daniel et al. (2026) explore the readiness of the UK construction industry to adopt digital technology to manage health and safety. In this study, readiness is the extent to which the organisation and project team are prepared to deliver a project based on MMC approaches and principles. It is therefore important that construction teams apply the same rigour and preparedness as those in industrialised factory facilities to ensure cost reduction, quality improvement, and accelerated delivery.

This research aims to identify current challenges in integrating MMC into conventional construction and to propose ways in which LC can assist with process improvement. To address the research, the following questions are posed: **RQ1 – What problems are encountered by MMC installers on construction projects? RQ2 – How can a Lean Construction approach support smoother MMC integration on construction projects?**

LITERATURE REVIEW

MODERN METHODS OF CONSTRUCTION

MMC encompass a wide array of building techniques and products, typically characterised by manufacturing processes conducted within factory environments rather than on-site (Rahman, 2014). MMC encompasses a wide spectrum of approaches, including assembling entire homes

from factory-manufactured volumetric modules and implementing advanced techniques for on-site placement of concrete blockwork. MMC includes the fabrication of complete three-dimensional units or modules such as bedrooms, bathrooms, and kitchens that are constructed off-site (NHBC, 2018). This volumetric construction is defined by creating spatial units, which are then transported to the building site for integration, often by stacking modules to form multi-storey structures. MMC covers the production of flat, two-dimensional units or panels, which are also manufactured in factory settings. These 2-D panels serve various structural functions, including walls, floors, and roofs, and are assembled and incorporated on site. The distinction is occasionally drawn between open panels, which provide only skeletal frames, and closed panels, which incorporate lining materials, insulation, electrical systems, and other integrated components. Materials used for panelised systems include timber, light steel or light gauge steel framing, precast concrete, structurally insulated panels, insulated concrete formwork (ICF), and cross-laminated timber (CLT) (DHLGH, 2022).

The designation ‘modern’ in MMC can be contentious and misleading, as precast concrete has been widely used for a long time, and timber-framed buildings are similarly established. The terminology surrounding offsite construction and MMC is subject to varying interpretations, with some using these terms interchangeably and others drawing distinctions (Green, 2022). According to a recently published government guide, there are seven categories of MMC. Category 1 comprises 3-D primary structural systems, also referred to as volumetric MMC, while Category 2 encompasses 2-D panelised components. The remaining five categories primarily feature non-structural elements, such as manufactured, non-load-bearing partition walls, but also include on-site technological advancements, including robotics, drones, process improvements, and other innovations (DHLGH, 2022).

Over decades, the construction sector has been widely recognised as facing persistent challenges, including fragmentation, suboptimal productivity, narrow profit margins, limited investment in capital and research and development, and ongoing skills shortages due to difficulties in attracting highly qualified talent (Farmer, 2015). Adopting factory-based building approaches offers opportunities to address or alleviate stagnant productivity levels through MMC integration. MMC facilitates significant product standardisation, enabling output improvements through iterative learning and process repetition (Rahman, 2014; Rushton, 2022). Furthermore, MMC generates less waste than traditional construction practices and accelerates project delivery times (Galster and Ok Lee, 2021). While estimates vary, construction periods for housing may be shortened by 4 to 6 weeks, reducing the overall project duration by up to 8 weeks (IBEC, 2021). MMC applies a production process to construction, minimising variability in practices typically executed on-site during traditional construction projects. The main advantages of MMC compared with traditional construction are time and labour savings, resulting in increased productivity and improved tolerances in more controlled factory environments (Searson, Leuchtenberg, Esposito, 2022).

Although off-site production presents numerous advantages, several obstacles remain in scaling MMC and making it acceptable in conventional construction practices. The literature categorises the barriers into eight broad groupings: cost, skills and experience, motivation and culture, tools and standards, the market for MMCs, industry, interface and flexibility, and projects (Rahman, 2014). The primary obstacle to wider use of MMC is its higher cost compared to traditional construction methods (Rahman, 2014; Layon et al., 2024; Saad et al., 2025). Because of this expense, many contractors are reluctant to adopt MMC unless the advantages accruing can be recovered from the customer. The novelty of some MMC products also makes stakeholders such as developers, consumers, funders, and insurers hesitant, as they do not fully understand the associated risks (Sweeney, 2024). Several factors contribute to these higher costs. While general demand for MMC remains low and forecasts are uncertain, manufacturers are prevented from achieving economies of scale. This limited demand is both a

result and a cause of MMC's greater expense and perceived riskiness. According to Saad et al. (2025) a misunderstanding of client's decision-making and procurement requirements. Furthermore, regulatory requirements increase costs because many MMC products have yet to be thoroughly evaluated or widely accepted, unlike conventional construction materials (Green, 2022). Rahman (2014) also noted inflexibility to late design changes is the most important barrier, alongside cost-related concerns and interface issues.

LEAN CONSTRUCTION APPROACH IN MODERN METHODS OF CONSTRUCTION

Lean Construction (LC) has evolved in response to challenges in construction and has incorporated Lean production techniques and principles to improve construction management (Koskela et al., 2019). The Last Planner® System (LPS) is an essential production planning and control tool in LC (Ballard and Tommelein, 2021). Its main functions include master/milestone scheduling, phase/pull planning, look-ahead and make-ready processes, weekly work planning and commitments, daily coordination huddles, and continuous learning and action (Ballard, 2000; Daniel et al., 2015). Takt theory and its associated concepts are central to the design of production systems, with the Toyota Production System recognising Takt as a key contributor to its overall success (Haghsheno et al., 2016). In construction, Takt time planning seeks to synchronise the production rates of different trades by pacing work sequentially through well-designed zones. This approach enables a continuous workflow, reliable handoffs between teams, and creates ongoing opportunities to improve the production system (Frandsen et al., 2013). The overarching aim is to maintain efficient use of resources whenever possible, whilst also striving to devise the most optimal production system solution (Lehtovaara et al., 2020). The application of production science within this framework allows for the establishment of continuous flow where feasible, and facilitates the management of buffers, such as additional crew capacity, to absorb variability (Frandsen et al., 2014). By making planning more visible and transparent, Takt concepts contribute to a more controlled and reliable construction workflow.

Despite a proliferation of industry- and government-initiated reports encouraging MMC adoption, there is a lack of mainstream academic literature on integrating MMC with both conventional and LC. Kemmer and Marin (2024) discuss both the difficulties and benefits of implementing a prefabricated timber frame system to achieve an ambitious objective in a Brazilian social housing project. This case study used Lean methods (LPS, Takt, Just-In-Time, BIM, DfMA, First Run Study) to effectively deliver 518 housing units in 10 months.

Outside of this example, the gap in peer-reviewed research means that much of the available guidance on MMC is shaped by policy and industry perspectives, potentially overlooking rigorous academic scrutiny that could provide deeper insights into implementation challenges and long-term impacts. As a result, practitioners and policymakers often rely on anecdotal evidence and sector-specific reports when making decisions about MMC integration, which may not adequately address the complexity or diversity of construction environments. Green (2022) refers to the debate on MMC as 'overhyped'. This underscores the need for systematic research and critical evaluation to inform best practices and support evidence-based decision-making in the sector, bridging the disconnect between practice-driven recommendations and academic analysis as construction moves toward greater adoption of MMC. Indeed, this paper is a first step in this direction, illustrating how LC can support smoother MMC integration on projects.

METHODOLOGY

To address the research question, a mixed methods approach utilising a case study was adopted, incorporating semi-structured interviews with both MMC providers and construction companies and systematic observation recorded on several site visits. This integrated

methodology enabled a comprehensive examination of issues and concerns from both provider and customer of MMC.

Case studies are widely used in construction research due to their effectiveness in capturing the specific contexts in which knowledge is acquired (Flyvbjerg, 2006). Yin (1993) highlights that case studies are particularly valuable for investigating the 'how and why' of phenomena, offering insights that quantitative approaches may not provide. Although questions regarding generalisability persist, Tellis (1997), referencing Hamel et al. (1993) and Yin (1993), contends that the number of cases does not solely determine the validity of a study; even a single well-chosen case can fulfil research objectives. Fellows and Liu (2020) assert that theoretical generalisation is achievable when samples accurately represent the target population. Across sectors and disciplines, numerous rigorous case studies are essential for developing a comprehensive body of knowledge (Flyvbjerg, 2006). Furthermore, Saunders (2012) emphasises that appropriate sample selection is critical to addressing the research question effectively.

Researchers adopt semi-structured interviews to capture focused areas while offering flexibility to tailor questions according to the specific context (Saunders, 2012). This enables interviewers to respond adaptively to interviewees, introduce new queries emerging from the discussion (Bryman and Bell, 2015), and allocate time efficiently. Additionally, face-to-face interviews allow for the observation of non-verbal communication, such as gestures and facial expressions, thereby enriching the quality of the interaction.

Structured observation was chosen for its ability to witness and record challenges and successes with MMC integration at the construction site. This improves data quality by observing behaviour rather than relying on surveys (Bryman and Bell, 2015).

CASE STUDY CONTEXT

This research involves interviews and observations conducted on six construction projects in Ireland, all of which were implementing MMC. The projects are two residential housing projects, three high-rise apartment projects, and a marine infrastructure project. The interviewee sample was selected from the eight MMC companies' operations managers who are directly involved in the installation interface on the construction project and from the six construction companies' site managers who were receiving the MMC products. This gave a population of 14 interviewees from the six case projects. The interviews ranged from 15 to 25 minutes long.

Due to its interpretative method and capacity for some quantification, content analysis is suitable (Bryman and Bell, 2015), aiding in measuring qualitative interview and focus group results. This flexible approach allows for both hypothesis testing and theory building, aligning with the deductive theory-building framework. The transcribed interview was coded based on Braun and Clarke, 20006.

RESULTS AND DISCUSSION

The following subsections present findings for the authors' research questions, exploring challenges for MMC installers, and the impact of implementing LC in conjunction with MMC, respectively.

PROBLEMS ENCOUNTERED BY MMC INSTALLERS ON CONSTRUCTION PROJECTS (RQ1)

The findings outline the problems encountered during the installation of MMC components, as identified by both MMC companies and contractors.

Site Readiness and Coordination

Many issues stem from sites not being adequately prepared for MMC installation, leading to postponements, increased storage and transportation costs, and inefficient trade sequencing. An

MMC component provider interviewee noted – “...the biggest issue we have is the site not being fully ready to accept our delivery, and to allow immediate erection of our timber frame kit from the truck.” Coordination between site teams and MMC providers is often lacking, resulting in misaligned access routes and delays. Figure 1 shows balconies stored on-site awaiting installation, using valuable ground space, susceptible to damage, and uncertainty around when they will be installed. Figure 2 presents the challenge of incorporating an internal wall panel system, erected out of sequence, with in situ concrete floor, timber trusses, structural steel, and precast concrete stairs. These partitions should have been erected before the ceiling and roof timberwork but a design change delayed production of the panel. The contractor stated: “...we would have been quicker doing this work with our own trades persons in the traditional way.”



Figure 1: Balconies awaiting installation



Figure 2: LGS wall panel

Drawing and Specification Discrepancies

Errors arise when revisions to drawings and specifications are not updated or reflected in MMC products or fabrication plans. This leads to setting out errors, insufficient or excessive tolerances, and installation challenges. An interviewee said: “...once our doors go into production there is no stopping the process. The door will come to site and we will install it. Any late change necessitates ordering a new door plus the extra cost of removing the already installed door.”

Inflexibility and Adaptability

Both MMC companies and contractors highlight inflexibility in delivery schedules, adapting products to incorporate change, or accommodating variation in measurements and design. This rigidity hampers the ability to respond to evolving project requirements.

Interface and Tolerance Challenges

Problems frequently occur at the interfaces between MMC components and traditional construction elements, especially with misalignment, inappropriate tolerances, and the integration of multiple construction systems (e.g., structural steel, precast concrete). An interviewee noted: “...our production system and pricing model necessitates manufacture of as many similar items as possible between production set-ups. More setups minimises any advantage over traditional stick-build techniques”

Quality and Workmanship Concerns

Issues related to quality such as poor protection of finished pods, component robustness, and workmanship errors, lead to rework, increased costs, and scope for subsequent trades. Figure 3 presents errors in foundation work with the rising wall too high, impacting timber frame house installation and causing a two-week delay while the block wall level was reduced, the radon integrity was restored, and the floor slab was recast before the timber frame partition could be erected.

Figure 4 shows scaffolding not being completed on time, causing the postponement of the timber frame kits by one week, necessitating the storage of the kits and the rescheduling of specialist resources and equipment.



Figure 3: Rising wall too high



Figure 4: Postponement of timber frame kit

Dependence on Other Trades

MMC installation success is often contingent on the timely and adequate progression of preceding or parallel trades (e.g., scaffolders, specialist crews), highlighting the need for integrated planning and resource management.

Complexity in Approval and Review Processes

Lengthy review and approval cycles for design can disrupt manufacturing timelines and add costs, underscoring the necessity for streamlined approval procedures.

Table 1 presents the key interview findings, and the issues raised point to a siloed approach on both sides. MMC companies emanate from a culture of production and manufacturing-based approach which is more disciplined and structured than the variation and variability that distinguishes prevailing site construction practices.

A key finding shows issues occur at the interface between MMC and traditional construction. When an entire structure can proceed with the MMC alone, there is a distinct reduction of issues. An interviewee noted: *“...if this building was constructed entirely with Light Gauge Steel, we would have far less issues. The problems occur where different materials and components meet with one another.”*

By prioritising the identification and management of these critical interfaces, projects can significantly reduce the risk of delays, rework, and quality deficiencies that commonly arise when MMC components are integrated with conventional construction methods. This requires a systematic approach to interface planning, including early engagement between designers, manufacturers, and site teams to ensure technical alignment and clarity on tolerances, delivery sequences, and installation requirements.

Traditional planning methodologies struggle to accommodate change, and the study exposes an absence of focused look-ahead planning to enable effective MMC acceptance and installation. An interviewee noted: *“...site management sometimes don’t understand that installation of many MMC elements (precast, timber frame, LGS, balconies, bathroom pods) all require safe access and setup areas for cranes and working platforms. This quite often causes significant disruption if not planned properly.”* Enhanced collaboration and the adoption of production-based planning tools, such as the LPS and Takt, will foster greater discipline and foresight, leading to improved site readiness and smoother integration of MMC elements.

A proactive focus on interface coordination and quality management will enable the benefits of MMC to be fully realised within hybrid construction projects. MMC is designed, procured, manufactured, delivered, and installed with a production and manufacturing-based mindset. Lean practices are default in manufacturing settings and methods like Design for Manufacturing and Assembly, BIM, Built-in-Quality, Material Requirements Planning, Just-In-Time, Takt

Time are built into daily and weekly routines. This mindset and approach are not as commonplace in construction site practices, and this absence of discipline and diligence contributes to the conflict that sometimes occurs, leading to breakdowns. It is critical therefore, that construction adopts a similar approach to that in MMC; a production-based mindset and practice implementation will reduce or eliminate some of the concerns around site readiness. Effective look ahead planning as espoused in Last Planner System and discipline accruing from Takt Planning are solutions that would address this issue. Stricter compliance around site quality and tolerance management would reduce another area of concern.

Table 1: Key interview findings

MMC Company	Issues identified by MMC	Issues identified by contractor
Timber Frame Housing A & B	Site not ready leading to postponement. Setting out errors. Discrepancy between site and MMC drawings. Access routes inappropriate.	Drawing revisions not reflected in MMC product. Inflexibility in delivery times & dates. Difficulty in accommodating change.
Precast Concrete Components	Long review & approval process reducing manufacturing setup & curing time. Site not ready leading to storage & transportation costs.	Need specialist installation crew availability. Temporary works can be large scope requiring design. Tolerances can be too big leading to extra site work. Inflexibility of surface finish options.
Balconies	Site not ready leading to storage & transportation costs. Setting out errors. Needing to align with scaffold drop sequence. Reliance on other trades like scaffolders resourcing to keep workflow.	Balconies looking to come to site too early. Looking for fast scaffold drops to hold installation efficiency.
Light Gauge Steel	Interface with misalignment with concrete and precast components causes issues. Errors in existing site work disrupts install. Other trades are insufficiently advanced to allow predictable workflow.	Inflexibility towards accommodating variation in measurements. Difficult to accommodate change in design or layout. Using other elements (structural steel, precast concrete) in their build solution can cause delays and extend design & approval process.
Window & Glazing Systems	Inaccurate opening formation. Updated drawings not incorporated into fabrication drawings.	Longer lead items measured off drawings resulting in insufficient tolerance to allow installation. Revised drawings or specification not captured by manufacturer.
Bathroom Pods	Transportation challenges to access craneage. Poor protection of finished pods during site works.	Issues with robustness of pod structure and finishes.
Steel Stairs Systems	Poor workmanship with infilling concrete steps resulted in rework for contractor	Infilling tolerances leads to rework, cost increase & extra scope for following trades

IMPACT OF IMPLEMENTING LC IN CONJUNCTION WITH MMC (RQ2)

The previous Section presents the challenges of installing MMC on-site. This section discusses the potential of the Lean Construction approach in addressing the challenges identified above.

Introducing a Production Planning & Control System

Incorporating a robust production planning and control system is essential for bridging the gap between design intent and site execution (Ballard and Tommelein, 2021), particularly when deploying MMC alongside traditional construction (Kemmer and Marin, 2024). Enhanced integration and communication between design and construction teams—supported by increased visualisation and ready access to technical designer expertise—ensure that interface

requirements are clearly understood and proactively managed. Using the Last Planner System to address short-term scheduling challenges further strengthens coordination, enabling site teams to anticipate and resolve potential bottlenecks before they escalate (Daniel et al., 2017).

A Lean Quality system

Implementing a Lean Quality system to manage tolerances involves embedding rigorous quality checkpoints throughout the production and installation process, underpinned by clear standards for measurement and acceptance criteria (Oakland and Marosszeky, 2017). This approach leverages real-time data capture and feedback loops, enabling teams to promptly identify deviations and enact corrective measures before tolerances become problematic onsite. Enhanced collaboration between design and construction teams, facilitated by advanced visualisation tools and readily accessible technical designer input, ensures that potential interface issues can be anticipated and resolved during the planning stages.

Balancing the push for MMC standardisation with contractors' requirements for flexibility, and harmonising production-driven approaches with conventional practices, remains pivotal in mitigating interface and quality complications and fostering smoother project delivery.

Factory and Site Interface

A central challenge in integrating MMC with traditional construction is balancing the need for standardisation inherent in MMC with the flexibility required by contractors (Rahman, 2014). This tension often manifests as a mismatch between a production-driven mindset and established on-site traditional practices.

Effectively addressing challenges at the intersection of MMC and on-site construction requires a strategic approach that integrates standardisation with flexibility to adapt to site-specific conditions. MMC relies heavily on standardisation to optimise production processes and improve operational efficiency. However, it is equally important to account for site tolerances and the unique demands of onsite installation. As this study illustrates, the convergence of pre-constructed components and onsite elements often presents interface challenges as MMC products are delivered and integrated onsite (Rahman, 2014).

It is essential to deliberately expose disconnects between factory and site operations, openly present the challenges encountered, and collaboratively develop solutions.

Balancing Traditional and MMC Approach

MMC relies on consistent standards to ensure repeatability and efficiency in offsite production (Mandala and Nayaka, 2025). However, contractors require adaptability to respond to unique site conditions, necessitating a flexible approach to interface management. When these differing requirements are not carefully aligned, it can lead to inefficiencies and increased costs.

Bridging the gap between standardisation and flexibility requires a deliberate, collaborative effort to align factory-driven processes with the realities of onsite construction. Facilitating early and open dialogue between design, production, and site teams can help ease the pressure of early design freezes and scope definition, empowering site management to adapt more confidently to MMC's pace and requirements (Rahman, 2014).

Moving Towards a Production Mindset

The energy and rigour applied in the factory environment are not always matched onsite. Offsite policy and processes can become inefficient if onsite practices are not adequately prepared or aligned, highlighting the need for equal attention to both operations. Addressing this disconnect is critical for maximising the benefits of MMC. By encouraging a production mindset across the project lifecycle, fostering regular feedback loops, and prototyping operations ahead of full-scale rollout, teams can identify and resolve potential disconnects early.

Furthermore, enabling collaborative alignment and maintaining clear, consistent communication between offsite and onsite teams are essential for bridging operational gaps. By strategically aligning both sides through shared lessons, integrated design and construction processes, and proactive knowledge exchange, projects can mitigate negative perceptions and avoid unnecessary costs or delays (NHBC, 2018; Wang and McCrum, 2024). This approach not only supports smoother MMC installations and heightened quality control but also ensures that knowledge and improvements are continuously fed back into both factory and site operations, laying a robust foundation for more efficient project delivery and positive outcomes.

Ownership of Technical Alignment

In addition to appointing a dedicated interface coordinator who possesses both technical design expertise and a strong grasp of on-site operational realities, it is crucial to foster early and ongoing collaboration among MMC providers, design consultants, and site teams. Such collaboration ensures that critical interface requirements are identified, communicated, and validated from the outset, reducing the potential for misalignment during installation. Embedding structured feedback mechanisms—where learnings from each project phase are captured and shared further refines integration processes and promotes adaptive problem-solving.

Collaborative Alignment and Clear Communication

Strategic alignment through equal attention to both offsite and onsite operations, shared lessons, and robust integration between design and construction can mitigate negative perceptions and prevent additional costs or delays (Kemmer and Marin, 2024; Saad et al., 2025). This collaborative framework supports smoother MMC installations, improved quality control, and a more efficient exchange between the factory and the field, setting a foundation for improved outcomes and positive project perceptions.

- Devote equal focus to both offsite and onsite operations to ensure seamless integration and efficient workflows.
- Establish regular communication channels and facilitate the exchange of lessons learned between teams to foster understanding and continuous improvement.
- Prototype operations ahead of mass production to identify and resolve potential disconnects before they escalate, ensuring that processes are refined and robust.

Considering Lean procurement and contract delivery solutions such as Lean Project Delivery, Target Value Delivery, and Integrated Project Delivery will facilitate early collaboration and agreement on design solutions, thereby removing key barriers to more complete MMC integration.

CONCLUSION & RECOMMENDATIONS

The aim of the study is to identify current challenges in integrating MMC into conventional construction and to propose how LC can assist with process improvement. The study found that a lack of on-site readiness, interface and tolerance challenges, waiting and reliance on other trades, and complexity in approval and review processes are among the challenges of integrating MMC on-site.

The study argued that to overcome these challenges, it is imperative to shift entrenched attitudes and promote a culture that embraces innovation and trust in MMC solutions. A better understanding of the client's role and decision-making is a key enabler of greater MMC adoption. The client can influence the prioritisation of early and active collaboration among design, manufacturing, and onsite teams, and concerns about increased onsite workload. The study found that facilitating targeted training, using Lean principles such as the LPS to support

transparent communication about programme expectations, and providing visible leadership support for MMC adoption will help dispel misconceptions and foster a more receptive environment. A limitation of the study is that it focuses specifically on the site interface where MMCs are integrated with traditional methods. Wider research should focus upstream on the design and decision-making processes and downstream on mitigating the impact of negative experiences from errors or mismatches in integration.

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