DESIGN

Modern Methods of Construction

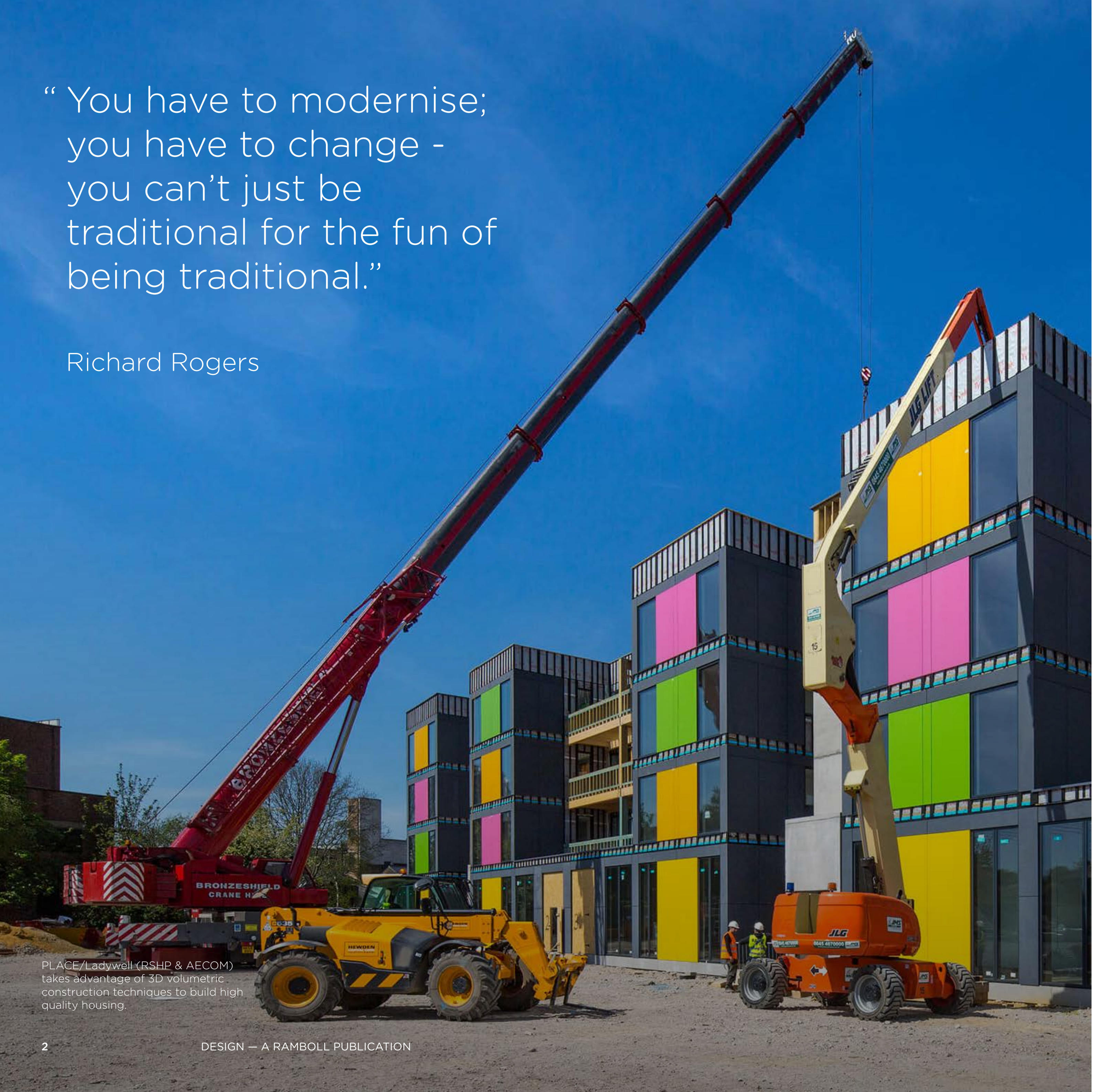
STATE OF THE ART

RAMBØLL

SPECIAL EDITION
MAY 2024

" You have to modernise; you have to change - you can't just be traditional for the fun of being traditional."

Richard Rogers



PLACE/Ladywell (RSHP & AECOM) takes advantage of 3D volumetric construction techniques to build high quality housing.

Contents

Executive Summary

Modern Methods of Construction (MMC) involves the use of manufacturing and industrialised processes to significantly reduce the project execution time, while improving the safety and sustainability.

Conventional construction presents challenges, such as being labour and time-intensive, requiring high carbon footprint and producing significant levels of noise and waste. The use of industrialisation and prefabrication can overcome such challenges, offering a wide range of solutions, from prefabrication of structural elements to the manufacturing of pre-finished components such as panelised, volumetric, MEP or bathroom pods or hybrid systems.

The edition will investigate various aspects of prefabricated modular construction that need to be considered while opting for MMC technologies for a given project. Some of the factors that will be discussed include the importance of a competent team, project-specific constraints, location, schedule, budget, site and logistics constraints, design ambition, and compliance with local codes

This edition of DESIGN is one part of a two-part publication on Modern Methods of Construction (MMC). This special edition explores the trajectory of MMC through various phases in history and presents the state-of-the-art of this technology to reflect on the global challenges, limitations, and potential improvements in the current approach.

The second part, slated for publication in June 2024, will cover MMC in a more general and informative manner for all who are interested in the topic.

MMC technologies adhere to the industry's highest quality standards, offering precision-built solutions with adaptability to a broad spectrum of architectural ambitions. Modular building designs are created using an interoperable digital platform including parametric tools, Finite-Element and Building Information Modelling enhancing material optimisation with a minimal amount of waste, designed for quick assembly and flexibility. This design process promotes efficiency and repeatability while preserving the building aesthetics, making MMC technologies suitable even for highly ambitious architectural designs.

In recent years, we have witnessed a rapid increase in adoption of MMC technologies, from prefabrication of 1D elements to prefinished volumetric modular units, particularly in regions undergoing rapid urban development. This marks a notable departure from the past decades when several countries experienced significant urbanisation relying on conventional construction methods. The current shift reflects a transformative trend towards innovative design and construction practices.

MMC has the potential to reshape the future of the built environment, promising up to 50% increase in construction speed, reduction in project costs, enhanced design efficiency, improved quality and safety, lower carbon emissions, and the creation of a more resilient urban landscape.

KAJ16 (Dorte Mandrup & Ramboll)
A multi-storey mixed-use residential and commercial building uses hybrid concrete and timber solutions and reuses material's from the site's original structure.

Introduction

Understanding the Terminology

Before delving into the edition, it is crucial to clarify and distinguish the **terms used in this paper** for better understanding.

Modern Methods of Construction (MMC),

refers to innovative techniques, materials, equipment, and technologies often involving manufacturing, prefabrication, and the use of advanced materials and technologies to streamline construction and deliver projects with enhanced quality and speed, such as the use of automation and the development of a manufacturing production line.

Prefabrication

describes a manufacturing process involving the production of modules in a controlled manufacturing environment. A prefabricated building describes a complex system which components are constructed either partially or fully in a factory environment. Once manufactured, such components are delivered to the site where they are installed or assembled to form the final building system.

Design for Manufacturing and Assembly (DfMA)

is an innovative design approach focused on simplifying and optimising manufacturing and assembly, promoting efficiency and constructability.

Modular Construction

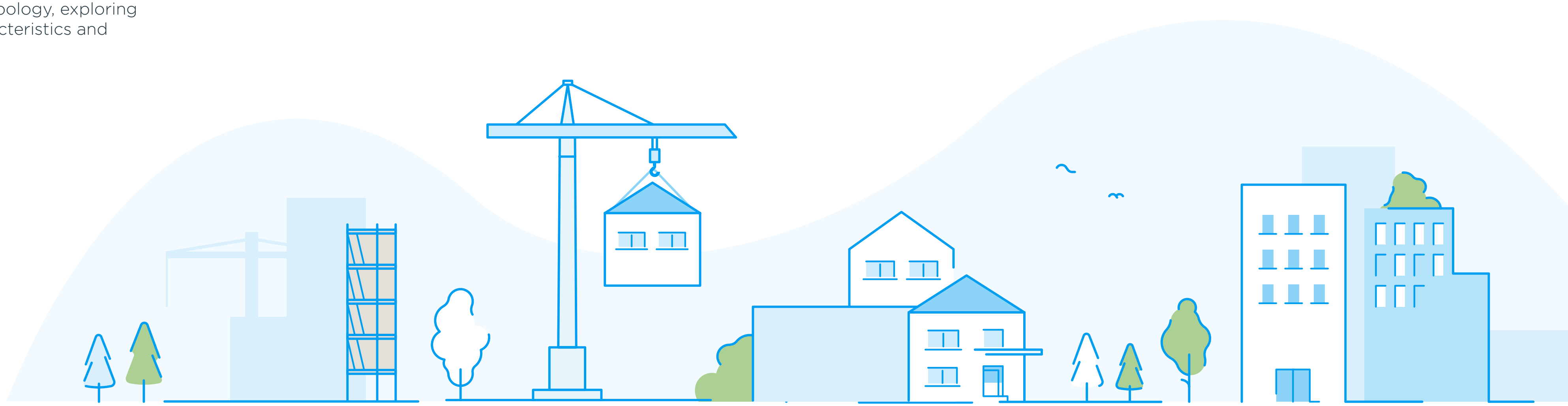
is an approach where specific or all components of a building are replicated, referred to as modules. These modules can encompass various system typologies, ranging from 1D single prefabricated structural components like beams or columns to 2D panelised systems, and even complete 3D volumetric systems that include structural, services and architectural fit-out components. The repetition of modules aids in the standardisation of design, achieving economy of scale and enhancing productivity.

1D Elements, 2D Panelised and 3D Volumetric Systems

represent distinct MMC system typologies within the space of Modern Methods of Construction (MMC). These classifications arise from the assembly of various components in factories, each offering unique advantages in prefabrication and construction. In the next sections of this document, we will expand on each typology, exploring their specific characteristics and applications.

From Construction Site to Assembly Site

MMC ›	Holistic and Innovative Method of Construction
DfMA ›	Design Approach
Prefabrication ›	Manufacturing Process
1D, 2D, 3D, PPVC ›	System Typologies
Modular Construction ›	Construction Methodology



MMC: What and Why

Challenges with Conventional Construction Methods

Traditional construction methods come with a set of challenges that have long been rooted in the industry's practices. The conventional in-situ construction, marked by its time-consuming nature and labour-intensive processes, often results in prolonged project durations and increased labour costs.

This approach, reliant on manual labour and vulnerable to weather conditions, poses safety concerns and contributes to the generation of significant material waste.

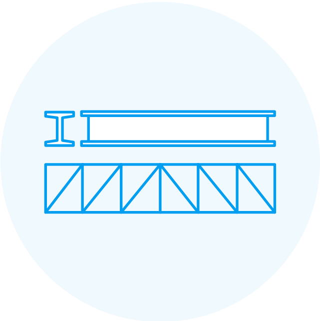
Furthermore, the traditional in-situ construction practices rigidly delineate responsibilities with much elaboration on the consequences of failure. This context fosters risk-averse behaviour, leading to a lack of collaboration and an adversarial construction culture.

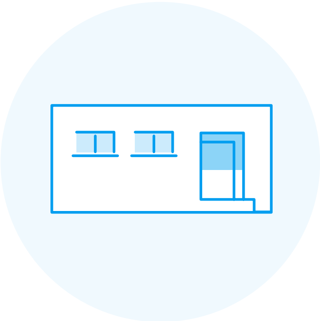
This affects all the stakeholders at various levels. Owners face monetary losses due to last-minute changes caused by uncoordinated designs, while architects and engineers strive to achieve the envisioned quality of work. Contractors bear financial burdens and risks in this fragmented process.

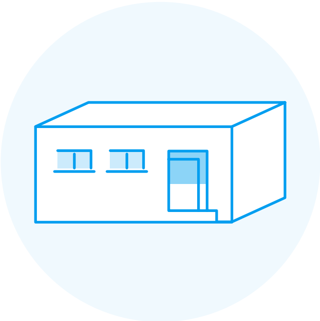
This fragmentation has been quantified in terms of waste and productivity.

Keilaniemen Portti, Finland (Architects Soini & Horto and Ramboll)
Standing at 60m, Keilaniemen Portti will be the tallest timber building in Finland and one of the tallest timber office buildings in the world. The use of timber in the project helped to minimise carbon emissions while enabling a high degree of prefabrication, which reduced the number of deliveries to the site and decreased the number of construction workers required on-site.

MMC System Typology







1D Elements

consist of individual structural components, such as beams or columns, which are prefabricated in a factory environment and assembled on-site. This approach significantly contributes to reducing the construction waste, while enhancing standardisation and improving productivity.

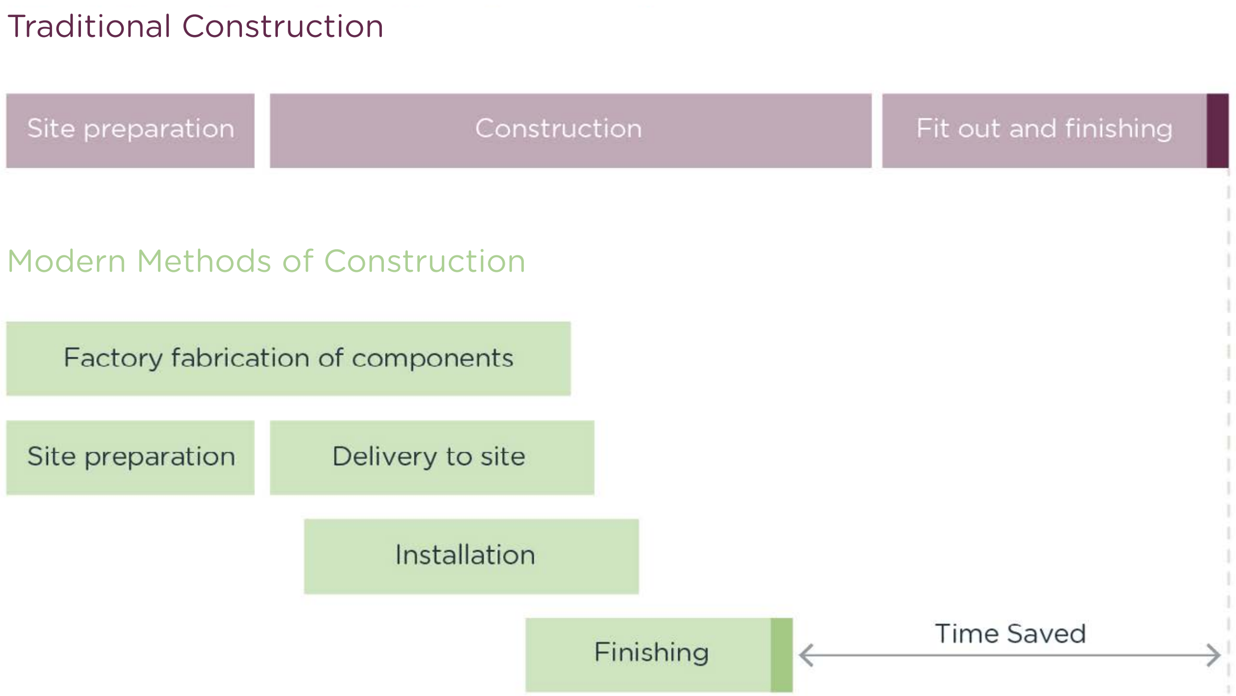
2D Panelised Systems

involve the prefabrication of building components, like walls or floor panels, which are then transported and assembled on-site. These prefabricated panels may incorporate various finishes, such as cladding, insulation, and interior surfaces, during the manufacturing process. This helps to streamline the construction process and ensures that a significant portion of the building's elements, potentially including finishes, are pre-assembled before being transported to the construction site.

3D Volumetric Systems

revolutionise construction by prefabricating components and assembling them to create complete volumes. The volumes are pre-assembled in factories and then transported to site for installation.
This offers the benefits of reducing on-site work, connections, promoting efficiency and ensuring the repeatability of the modular units.
To maximise the advantages of 3D volumetric construction, the assembly of these volumes may extend to include structural, services, and architectural components, to form fully assembled volumetric units. This system typology is known as Prefabricated Prefinished Volumetric Construction (PPVC).

Advantages of MMC



Comparison between Traditional Construction and Modern Methods of Construction schematic roadmaps.

1. Accelerating Construction Programmes

Prefabrication can proceed in parallel in the factory while other on-site activities are ongoing to streamline the construction process. Construction programme savings ranging from 15% to 50% have been demonstrated through numerous projects, attributed to concurrent site and factory work, faster factory production, quick on-site installation and elimination of uncertainties such as weather delays and subcontractor sequence delays associated with on-site construction.

2. Productivity Improvement

On-site construction activities can be significantly reduced through the use of prefabrication, potentially achieving over 40% productivity improvement in terms of manpower and time savings, depending on the project complexity. Projects involving prefabrication show up to 30% increase in labour productivity compared to traditional on-site projects, ultimately reducing risks associated with on-site construction. The productivity improvement intricately reduces project and construction risks. By shifting a significant portion of construction activities to a controlled factory environment, MMC minimises on-site risks such as accidents, delays due to adverse weather conditions, and disruptions caused by site constraints.

3. Better Quality Control

Prefabrication ensures that the majority of the final product is crafted within a controlled factory environment, resulting in heightened reliability and superior-quality of finishing, while reducing the risk for structural flaws. This approach allows for more efficient planning of the work sequence, facilitated by improved logistics coordination.

Lighthouse tower in Aarhus (3XN Architects & Ramboll)
The 44-storey building utilised hybrid precast concrete columns to expedite construction while maintaining the same strength capacity as a monolithic connection.

4. Reduced Disruptions and Better Construction Environment

Reducing disruptions and improving the conditions of the construction environment are critical considerations for any construction project, particularly those in noise-sensitive areas. MMC offers a solution by significantly reducing noise pollution. By conducting a substantial portion of construction activities in factories, MMC minimises disturbances for nearby residents and businesses. Moreover, MMC leads to fewer inconveniences such as road closures and less dust, enhancing the overall construction process. This approach ensures a quieter and more comfortable environment for stakeholders.

5. Reduction of On-site Manpower and Improved Safety

By replacing a significant amount of on-site construction activities with prefabrication, the workers will be working in a controlled factory environment with reduced safety hazards and minimised risks. Furthermore, fewer workers will be engaged in on-site activities, resulting in fewer accidents and less downtime. Therefore, improved safety conditions are achieved by reducing on-site construction time and individual man-hours working at height.

6. Advancing Circularity

MMC is pivotal in advancing circularity within the construction industry. The MMC approach minimises material waste by relocating a significant portion of the construction process to a factory environment. Prefabricating repeated forms reduces the likelihood of material waste while promoting a more sustainable operation. Transporting factory-produced modules to the site minimises material deliveries, reducing fuel waste and easing road congestion around the site. On-site waste is reduced by between 70% to 90% compared to the traditional on-site construction.

Furthermore, prefabricated components can be easily repurposed, extending their lifespan and minimising the need for new resources. Moreover, MMC prioritises recyclable materials, facilitating the closure of material loops and promoting a more sustainable approach to construction. By optimizing resource use and creating durable structures, MMC fosters a circular economy where materials are conserved, waste is minimised, and environmental impact is reduced.

7. Improved Sustainability

The adoption of MMC holds promise for enhancing sustainability within the construction industry. The use of MMC can significantly reduce the carbon footprint of buildings, primarily due to the opportunity it provides to utilise more sustainable materials and minimise the amount of concrete compared to conventional designs and construction processes. By embracing MMC, construction projects can leverage innovative materials and construction techniques that prioritise environmental conservation and resource efficiency.

Challenges and Constraints of Prefabrication

Embracing MMC holds a significant potential and can be the key enabler for efficiency and innovation in the construction industry.

However, this paradigm shift introduces some inherent difficulties that may hinder the benefits that MMC can offer to our projects and communities. It is imperative to address such challenges and constraints with appropriate consideration at both project and wider industry levels to ensure successful implementation. Some of these challenges are the following:

1. Selecting a Competent Project Team

This responsibility extends beyond the designers and involves stakeholders at different levels and responsibilities, including developers, contractors, manufacturers and installers. This challenge encompasses various considerations such as ensuring that the best engagement models are in place, including planning and implementation of contractors and manufactures involvement, such as Early Contractor Involvement (ECI) to enhance coordination and collaboration, system integration, improve interfaces while promoting opportunities for value engineering and aligning stakeholder interests to achieve project goals.

2. Initial Investment Costs

Upfront costs for setting up manufacturing facilities and acquiring equipment can pose significant financial challenges, especially for smaller businesses or start-ups. These costs may deter companies from considering the adoption of MMC solutions, potentially limiting innovation and industry transformation.

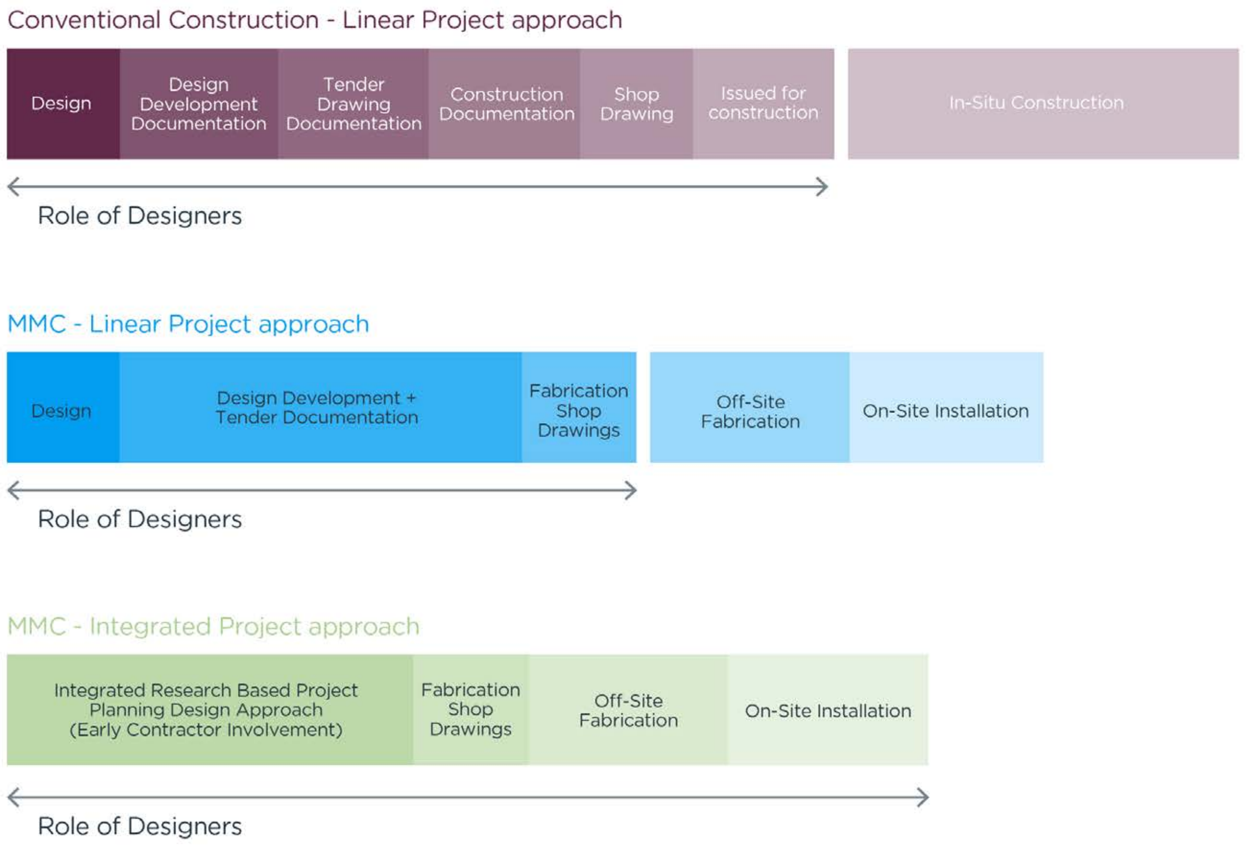
It is imperative for companies to carefully assess these costs, cash flow, project pipeline, and all associated risks, evaluating the return on investment as part of their business case analysis.

3. Efficiency and Standardisation Challenge

This challenge represents a specific aspect within the broader spectrum of design constraints outlined previously. While the adoption of MMC technologies has the potential to achieve cost-effectiveness, unlocking this potential requires design efficiency. Designers play a crucial role in selecting MMC systems that best suit project-specific requirements, considering various design aspects, constraints, and opportunities. The goal is to enable standardisation through efficiency and optimisation, in order to achieve both cost effectiveness and economy of scale. This aspect is critical to the achievement of efficiency, constructability and cost-effectiveness.

4. Technology Adoption Challenges

The complexity of transitioning to new technologies presents a considerable challenge for companies exploring MMC and manufacturing opportunities. This category includes the requirements for specialised training and skill development for staff involved in the design, manufacturing, assembly and installation of MMC technologies. Furthermore, lack of of regulatory frameworks can represent an additional challenge that stakeholders at various levels of the value chain face when adopting MMC.



Comparison of conventional construction (linear project approach) and MMC (integrated project approaches).

5. Design Constraints

Design constraints require early coordination with all designers and consultants on board. Such constraints comprise various factors, including the impact of MMC systems on floor and ceiling heights, as well as net floor efficiency. Understanding these complexities is essential for developing efficient design schemes that align with architectural expectations. Failure to address these constraints upfront can lead to conflicts, abortive work, delays, and inefficiencies during the design and construction phases of MMC projects. Effective communication and collaboration among project stakeholders are essential to optimising design solutions and minimizing project risks.

6. Logistics Constraints

Challenges related to transportation, handling, and coordination of materials, components, and finished products in the manufacturing process can significantly impact project efficiency. Factors such as limited transportation infrastructure, long lead times for deliveries, and complex supply chain networks may increase costs and lead to delays. Optimising logistics processes is essential to overcoming these challenges and reducing overall construction time.

Bella Sky Comwell Hotel, Denmark (3XN & Ramboll)
The Bella Sky Hotel consists of two towers leaning in opposite directions at a gravity-defying 15-degree angle. The superstructure consists entirely of prefabricated elements.

Current Barriers and Opportunities with MMC

In today's construction industry, stakeholders throughout the value chain are recognising the enormous potential of MMC to revolutionise project delivery and enhance industry efficiency. However, despite this increased awareness, there are still several barriers impeding the widespread adoption of MMC worldwide.

Addressing these obstacles is imperative to unlock the full potential of MMC. With the right vision, competence, and mindset, these challenges can not only be overcome but can also transform into opportunities, fostering innovation in construction. Below we explore the current main barriers preventing the implementation of MMC technologies at larger scale.

1. Regulatory and Approval Processes

The lack of suitable regulatory frameworks can create barriers to adoption. Proactive measures are essential, such as: collaborations with authorities to update building codes and approval processes; investing in R&D to demonstrate compliance with standards; government initiatives to streamline approval processes fostering MMC adoption, like in Singapore, Hong Kong and Dubai.

2. Lack of Appropriate Collaboration Models

The implementation of efficient project collaboration models presents a challenge that can prevent the development of MMC within the industry. Overcoming these barriers requires embracing more collaborative procurement models, such as Early Contractor Involvement (ECI), to enable contractors and manufacturers to contribute to the design phase. This fosters stronger partnerships and communication channels among stakeholders, ensuring seamless integration and maximising the benefits of MMC.

3. Scale and Market Maturity

Despite an increasing interest in MMC, the industry's current scale and maturity may not be sufficient to maximise its benefits. This can act as significant barriers, slowing the pace of MMC adoption and delaying the realisation of its potential advantages across the industry. Addressing these challenges requires concerted efforts to expand market reach, enhance industry collaboration, government support to promote awareness of MMC's advantages.

4. Skills and Workforce Development

The transition to MMC demands a proficient workforce in modern technologies and construction methods. However, shortages of trained workforce and lack of standardised training programmes can result in a barrier to widespread MMC adoption. Addressing these gaps through education and training initiatives is imperative for the development of a skilled workforce capable of driving MMC implementation forward.

Tate Modern, London, UK (Ramboll)
From the one-of-a-kind geometric structure to the striking brick façade, every aspect of this building has been planned and engineered with staggering precision using kit-of-parts components such as precast columns, precast cladding and soffit panels

5. Perception and Risk Aversion

Knowledge gap and resistance to change and challenge traditional practices can impede MMC acceptance. Stakeholders may perceive MMC as unable to meet the standard of quality, durability, and long-term performance compared to conventional methods. Overcoming skepticism requires demonstrating MMC's benefits through successful projects and promoting awareness of its advantages and capabilities within the industry.

6. Higher Initial Capital

Implementing MMC often requires upfront investment in equipment, technology, and training, which can be a barrier for companies accustomed to traditional construction practices. However, MMC often offers long-term cost savings. Strategic planning, thorough feasibility studies, cost-benefit analysis and value engineering excercises can optimise efficiency and costs, while assessing and mitigating business risks.

7. Supply Chain Development

The success of MMC projects relies on a well developed supply chain. Disruptions can cause significant delays. While the MMC supply chain has evolved, further enhancement is required. Such improvements can result in cost reductions while enhancing sustainability, particularly by mitigating carbon emissions associated with transportation.

Design for Manufacturing and Assembly

Focused on optimisation of product design, Design for Manufacturing and Assembly (DfMA) is a disruptive innovative design approach with the primary focus on promoting ease of manufacturing and assembly.

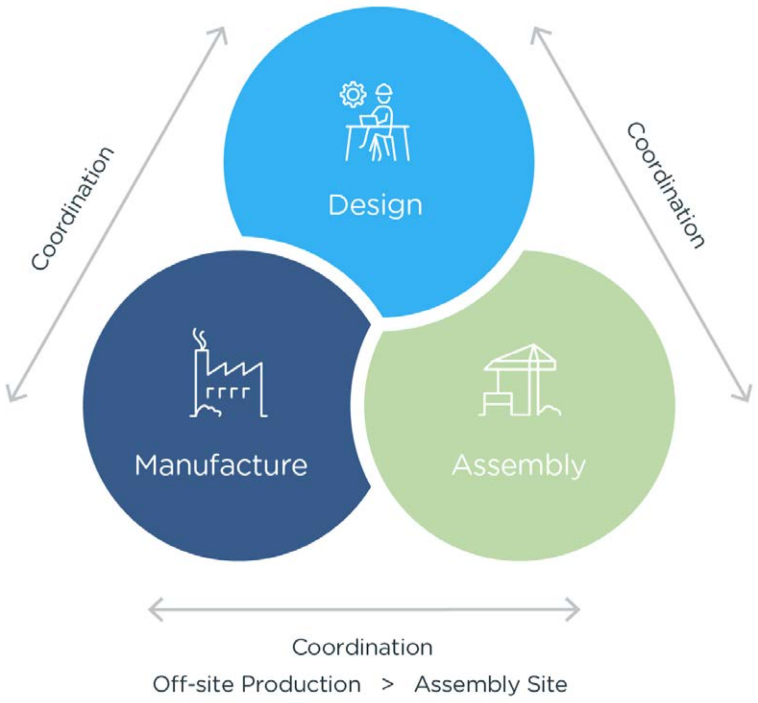
Key aspects related to DfMA include:

1. Simplicity and Standardisation

Simplifying product designs and standardising components wherever possible can reduce manufacturing complexities and costs. By minimising the number of unique parts and ensuring interchangeability, assembly becomes more efficient. This aspect overall improves the product efficiency and cost-effectiveness through the achievement of economy of scale.

2. Material Selection and Optimisation

Choosing appropriate materials to meet project specific requirements, such as strength, serviceability, sustainability, durability, cost, and manufacturability, and optimising material usage to minimize waste. Modern Methods of Construction (MMC) offer a significant opportunity to promote the use of low-carbon-emission materials, further enhancing sustainability efforts.



Design for Manufacturing and Assembly
Streamlined collaboration throughout design and construction.

3. Digital Design

Utilising advanced software tools can create, analyse, and optimise product designs in a virtual environment. Developing an inter-operable digital platform can enhance material optimisation, enabling faster iteration and streamline the design process, facilitating the integration between analysis, deliverable production and BIM, from the design to the manufacturing and assembly.

4. Design for Manufacturing

Optimising product designs to streamline the manufacturing process, including selecting cost-effective manufacturing processes and minimizing material waste. Additionally, design for manufacturing shall consider designing components for easy access during maintenance and repairs.

5. Design for Assembly

Designing products with ease of assembly in mind, prioritising safety for the team installing the components while minimising the number of assembly steps and the need for specialised tools or skills. This involves conducting detailed crane studies and planning the installation sequence to ensure efficiency and safety.

6. Early Collaboration

DfMA requires a collaborative approach among stakeholders to align the design with the proposed systems. This collaborative effort demands the implementation of the right engagement model, often involving Early Contractor Involvement (ECI), ensuring a seamless integration of design and construction processes.

7. Life cycle Considerations

Considering the entire life cycle of a product, including manufacturing, assembly, use, and disposal, will promote design decisions based on efficiency, sustainability, and cost-effectiveness. Design considerations should also include the disassembly, facilitating the removal of components and promoting the potential repurposing of the building at the end of its life cycle.

8. Design for Logistics

DfMA is crucial in identifying the most suitable logistics strategies tailored to project-specific requirements and site constraints. This includes route studies, from the factory to the site, considering limitations in size and weight. Additionally, the prefabricated products have to be designed for all the temporary loading scenarios, including manufacturing, transportation, storage, hoisting and site-assembly to preserve safety and avoid damage that can compromise the product's quality.

Exploring New Materials

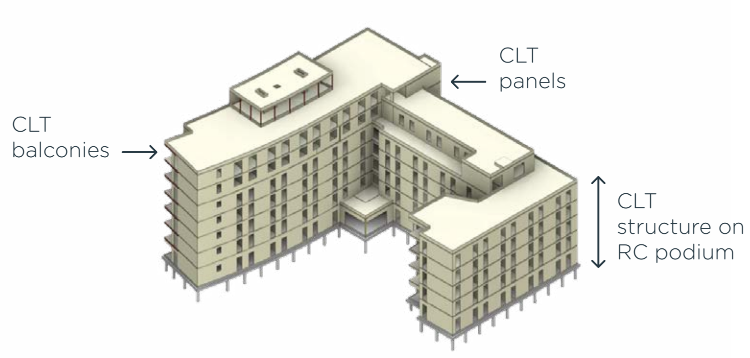
Timber is growing in popularity; preconceptions about fire, longevity, mortgages, insurance, and availability are being long forgotten, replaced by the material's many advantages. Also stacked in its favour are the benefits of shorter construction programmes due to prefabrication, good thermal and fire performance properties, lighter buildings' requiring smaller foundations and sustainability benefits, where we are often able to create a carbon neutral structure.

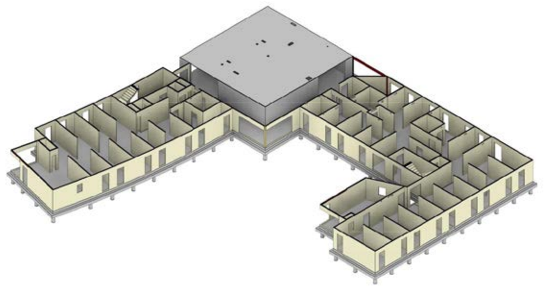
Furthermore, when large areas of a cross-laminated timber (CLT) structure is left exposed, it can create a striking architectural feature. Not only does this add great aesthetic value to the building, but can also yield many savings in interior wet trades as the large timber panels eliminate the need for a significant quantity of interior blockwork partitioning and plastering.

Timber is the only truly renewable building material. Using one cubic metre of wood in place of other materials results in the sequestration of 0.8 tonnes of CO_2.

By increasing the use of timber in construction, we are contributing to carbon storage in forest products. Coupled with the inherent properties of wood that make it thermally efficient and its ability to improve air tightness in CLT construction, timber becomes the most sustainable choice for construction. In addition to the immediate environmental benefits, construction sites building in timber are significantly less disruptive, creating a better working and surrounding environment, with quieter and cleaner site works, fewer trades required on site and fewer deliveries. This results in less noise and congestion, improving air quality.

In addition the efforts to fundamentally reduce carbon in the production of concrete and steel, both industries are also targeting Carbon Capture and Storage (CCS) technology to achieve their long-term net zero goals. While this technology presents significant technical and commercial challenges, it may be a necessary step in continuing to utilise the benefits of these materials and stay within our 1.5 degree carbon budget.





Dalston Works, Hackney, London, UK (Waugh Thistleton Architects & Ramboll)
The world's largest cross-laminated timber (CLT) project, employing more timber than any other scheme worldwide by volume. Except for the concrete podium, the entire structure is built of CLT, including floors, walls, and elevator cores.

History of Prefabrication

“ The past is a foreign country: they do things differently there.”

L.P. Hartley

Prefabrication has evolved from stone cut blocks, wooden beams or metal structures made in workshops or other locations using traditional tools and techniques.

The advancement in technology, materials, industrialisation and innovations, has transformed modern methods of construction. In the following chapter, we would focus on modularity and 3D volumetric PPVC.

Ancient Rome
5000 BCE

Natural cut

Blocks of stone were cut and transported to the construction site and assembled

16th Century
1624

Panelised Wood House

First panelised wood house from England to Massachusetts

Post Industrial Revolution
After 1840

Standardized 1D Elements

Metal parts of the Eiffel Tower were prefabricated (traced, cut and drilled) in a workshop. Two-thirds of the 2,500,000 rivets were inserted at the factory using machines

19th Century
1903

2D Panelised Elements

First prefabricated precast concrete panelled apartment blocks pioneered by John Alexander Brodie

Postmodern Era
Habitat ’67
1967

3D Volumetric Boxes

The large apartment building was featured in the Montreal World’s Fair.
It consisted of prefabricated concrete boxes referred as “modules” which were lifted and stacked by cranes and post-tensioned to create the stepped form

Early 21st Century
The Clement Canopy
2016

Prefabricated Prefinished Volumetric Construction (PPVC)

65% of the superstructures of two 40-floor tower blocks were constructed using PPVC making it the world’s tallest concrete PPVC building

Recent Applications

Recent Applications

3D volumetric construction methods, and particularly PPVC systems, are amongst the most efficient in the field of modular construction. In the past, 3D Volumetric Construction was associated with temporary or relocatable modular pods, such as construction site trailers and communication pods.

Currently, modular construction is widely used for residential buildings of 4 to 8 stories.

More recently, modern technology and advancements in design, manufacturing, and installation capabilities have made it possible to apply modular volumetric construction to high-rise buildings.

In this chapter, we will explore the global scenario and provide examples of recent 3D volumetric applications.

Spacebox, The Netherlands (Mart de Jong)
The Spacebox is a student accommodation. It consists of colorful prefabricated boxes stacked up to 3 storeys high and its 18m² per unit. Each apartment unit fully is equipped with a shower, toilet, bedroom, and a kitchen.

The Student Residence at Wong Chuk Hang, University of Hong Kong

Architect: AD+RG.
MiC Architectural Consultant: Alda Consultants
MiC Structural Engineer: Ramboll
Fabrication Specialist: iMax SG

The Student Residence at Wong Chuk Hang, University of Hong Kong (HKU), is one of the first examples of the implementation of Modular Integrated Construction (MiC) in Hong Kong.

With a gross floor area of approximately 25,000 m², the project comprises two 20-storey modular buildings.

It features two 17-storey modular towers supported on a non-residential three-storey podium.

Utilising 952 MiC units with only five variations of module sizes, the Student Residence at Wong Chuk Hang prioritises efficiency, streamlined construction timelines and cost effectiveness.

The MiC units were prefabricated and prefinished at a modular factory located in mainland China and subsequently transported to Wong Chuk Hang for on site installation.

The podium, which consists of a large multi-purpose hall, recreation rooms, library and activities room, serves as a transfer system for the above modules and is designed and constructed using conventional reinforced concrete construction method.

Reinforced concrete core walls are located at the centre of these buildings to serve as the lift core, fire staircases and MEP services as well as providing lateral stability.

Crowne Plaza Changi Airport Extension, Singapore

Architect: WOHA Architects
Structural Engineer: RSP Architects Planners & Engineers Pte Ltd (C&S)

The hotel's new extension was constructed using prefabricated Prefinished Volumetric Construction (PPVC) method.

PPVC method significantly reduced manpower required on site by 40%, from 75 workers, when using conventional construction techniques, to only 45 workers with the PPVC method.

It has nearly halved the needed manpower to construct its new extension, and reduced the time required for on-site works, to a third of the time needed by conventional methods.

The extension of the hotel, developed by OUE Limited, will be the first private-sector commercial building in Singapore to be completed using the PPVC method.

Off-site production of 252 units were carried out in Shanghai, China, before it was shipped to Singapore, to be assembled on-site. With the 100% off-site completion of the finishing works of the modules, PPVC resulted in minimal on-site works for the lobby and mechanical, electrical, plumbing and fire protection connection works to be completed. An average of ten (10) PPVC modules are assembled per day from 10pm to 5am.

Conventional method > 75 workers

PPVC method > 45 workers

40% ↓
Less manpower

Citizen M Hotel, Tower Hill UK

Architect: Sheppard Robson
Structural Engineer: Ramboll

Tower Hill will be a flagship location for CitizenM's London offer, comprising a 370 bedroom hotel in the setting of a UNESCO World Heritage site.

The new nine-storey hotel is partly built upon the former site of a five-storey 1960's office on the roof of Tower Hill station.

Lightweight construction was key. The new load paths from the new modular hotel had to compare favourably with the previous load from the office and the capacity of the existing station structure.

Modular construction was adopted to reduce weight, speed up construction, enhance quality and reduce wastage on site. The modules were manufactured in Poland, stored off-site in the Port of London dockyards, then brought into the City during the night for installation on site.

As part of the development agreement with London Underground, new step free access has been formed for the station. There are two ticket offices, one under the new hotel and the other through a separate building to the south. Each location has a new lift and stair access from platform to ground level.

Y-Cube, United Kingdom

Architect: RSHP
Structural Engineer: AECOM

The Y:Cube is an economical housing solution, developed by Roger Strik Harbour + Partners in South London in 2013.

The units are 26m² one-bed studios, for single occupancy, that arrive on site as self-contained units.

Each unit is constructed in the factory with all the services already incorporated.

Therefore, the water, heating and electricity can be easily connected to existing facilities or to other Y:Cubes already on site. This 'plug and play' approach results in a modular, demountable system of apartments that are perfectly designed for brownfield sites. Additional units can be added if needed and whole developments can be taken apart and rebuilt in new locations. This modern method of construction makes for a neighbourly, clean and quiet site.

Each unit is constructed from high quality, eco-efficient materials (primarily renewable timber).

The factory conditions in which the pods are assembled ensure tolerances of 2mm, creating accommodation that is so well insulated that they require little or no heating, even in winter months.

Y:Cube Housing is a modular system using volumetric technology that enables the factory-made units to stack easily on top and/or alongside each other, making it completely adaptable to the size and space available and therefore perfect for tight urban sites, creating semi-permanent communities.

461 Dean Street, Brooklyn, New York

World's Tallest Volumetric Modular Apartment Building

Architect: SHoP Architects
Structural Engineer: Arup

The size of a modular unit is: up to 4.57m width, from 6.10m up to 15.24m length, 3m height.

The average production speed is 4 modules a day, equivalent to one (1) floor per week.

32 floors, 109.4m

One of the illustrative example of high-rise building using volumetric modular system is the residential building 461 Dean Street, pacific park complex, Brooklyn district, New York. It is highest modular building in the world (32 floors, 109.4m).

In total 930 modular blocks we used for the construction of the building with 363 apartments. 225 types of modulus were designed and produced at the plant which was specially built for the building. The average production speed is 4 modules a day, equivalent to one (1) floor per week. It is to be noted that the production speed was not very high, but at the same time the projects showcases the possibility to achieve high quality and fully fit-out PPVC structure.

The fully fitted modules (including MEP services and finishing items) were delivered to the construction site by special trucks and installed at night. All parts of the building are fixed on steel columns with additional transverse crossbars to strengthen the structure.

An adaptation of this technology is to design a 'podium' or platform structure on which the modules are placed. This way, open space is provided for retail or commercial use or car parking. Support beams should align with the walls of the modules and columns are typically arranged on a 6 to 8 m grid (7.2 m is optimum for car parking).

Conclusion

Prefabrication can deliver a variety of building and construction types such as education, housing, health care, office, government, institutional, dormitory, retail, and hospitality. When understood and deployed by stakeholders intentionally, with early project planning, it is a well-suited solution to control project schedules and budgets while increasing quality and reducing environmental impact. Prefabrication is especially effective when employed to shorten building cycles, on repetitious or unique projects, and with teams that are prepared to embrace the challenges and opportunities associated with its delivery.

The Regenerative High-rise (Haptic Architects and Ramboll)
It is built on a modular logic. It has the main structure frame consisting of three-story-high structural decks. Each deck can support either three intermediate floor plates or three levels of versatile pods.

Among the various MMC System typologies, 3D volumetric and particularly PPVC represents a large opportunity to construct infrastructure in a quicker timeframe, use less manpower, concentrate skilled workers in one location, minimise dust and noise pollution on site, and improve sound insulation. The current challenges facing the 3D volumetric systems are a battle against inertia within the construction field, several logistical issues, higher costs, and a potential limiting of architectural design.

However, these challenges are being confronted. Government subsidies or mandates are encouraging the industry to try this new method, logistical planning can be done with a commitment to MMC technologies early on, innovation in module design can reduce the limitations for architectural design. Furthermore, the higher costs will likely be reduced as the PPVC is adopted on a larger scale.

MMC in its current usage is reflexively associated with modularity and hence it becomes mundane and restrictive for designers. However, to the letter of its definition, MMC doesn't have to be confined, or need to always have association with modularity.

With the changing times of digital fabrication, and in a future where the bespoke need not cost more than the repetitive, the MMC method is well poised to dramatically revolutionise the construction industry by combining the benefits of assembly line technology with the future of digital fabrication.

Further research of the MMC method should focus on ways to lessen the challenges involved. By researching new module designs and structural systems for MMC buildings, more cost effective designs could be found and more architectural designs could be realised with MMC. With better strategies to better plan for MMC's logistical challenges, projects will be more likely to reap the full benefits of adopting the MMC method.

This next generation of bespoke MMC, may play a key role in delivering many of the construction industry's current socio-economic responsibilities – not limited to the climate crisis and global housing crisis. MMC can advocate equality in manpower, by elevating those most at risk at site to higher skilled operators within the construction industry. Furthermore, the MMC method, with its plug-and-play assembly could be developed for deployment in refugee crises and disaster relief efforts. With research providing innovative solutions to the current inertia and drawbacks, MMC will ultimately become a more efficient process and a stronger alternative to traditional construction.

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