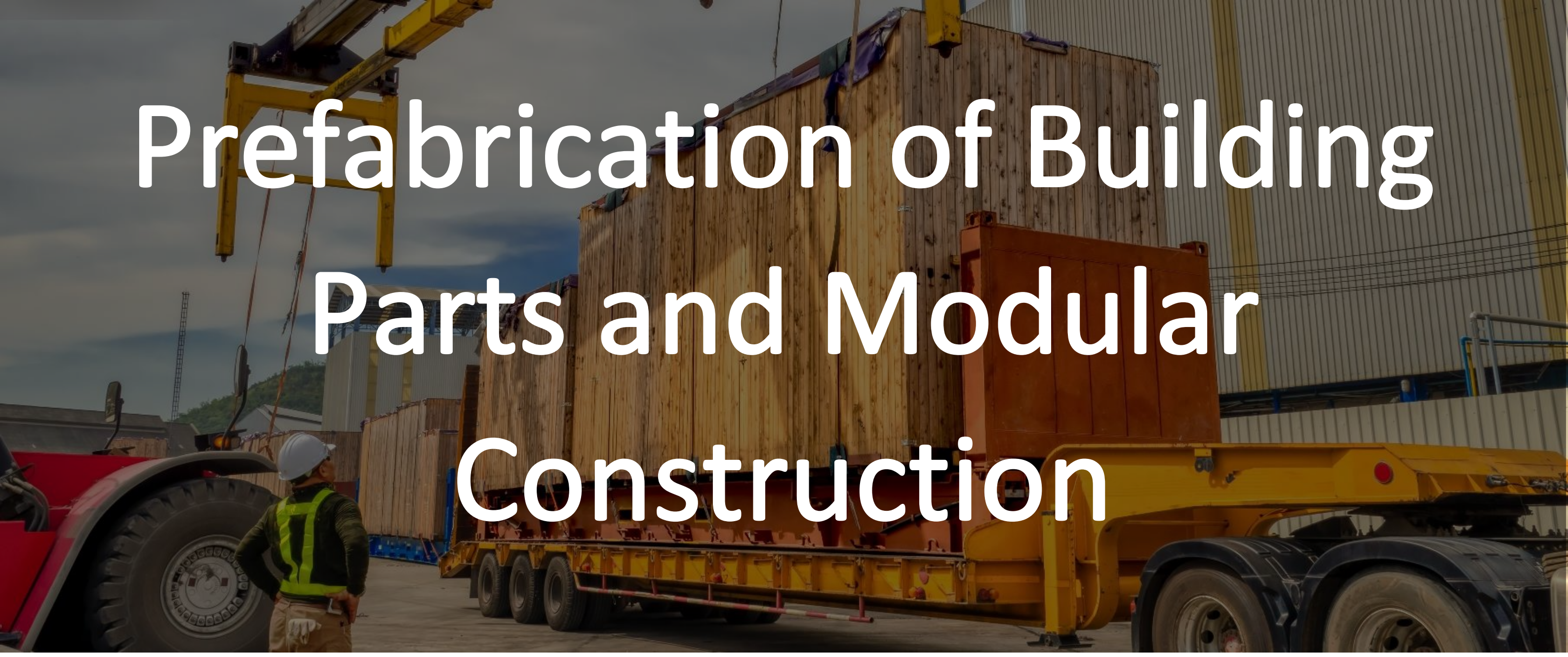


Prefabrication of Building Parts and Modular Construction

DETAILS

SECTOR | Transport and Energy

STAGE | Project Delivery (Construction)

TECHNOLOGIES | 3D Modelling, Building Information Modelling (BIM), Automation

SUMMARY

Prefabrication and Modular Construction are two processes involved in the construction of buildings and infrastructure. Prefabrication is the practise of assembling components of a structure off-site in a warehouse or other location and transporting the complete assemblies to the construction site. Modular construction is a method that involves constructing sections, or "modules", off-site and then delivering those modules to the construction site to be installed and joined together. These methods differ from traditional construction approaches, in which basic materials are transported to the construction site where the project team assemble all elements.

Traditionally these construction methods have varied in popularity by country and have experienced waves of adoption. Until recently, the perception of prefabrication and modular construction has been generally negative, with the quality of craftsmanship considered poor. Today, the potential benefits offered by prefabrication and modular construction are being recognized, combined with advances in technology and craftsmanship enabling more complex designs and the use of better materials.

Previously architects and engineers relied on 2D technical drawings done by hand or through computer aided design to develop components and oversee project construction. This resulted in many errors, that were typically recognized when prefabricated components or modules are transported to site for installation. Errors, particularly this late in the construction process, can cause significant delays and increase costs as those elements may need to be altered or produced again. This has knock on effects to the rest of the build schedule.

Today, Building Information Modelling (BIM) (*see also the 3D Infrastructure Modelling and BIM use case*) is being used in conjunction with these construction methods, to ensure that the prefabricated components or modules will fit together as intended once installed on the construction site. BIM enables the project to be built virtually before being physically constructed, which can eliminate many of the issues or inefficiencies that can arise during the construction stage. Utilizing this technology can give new life to prefabrication and modular construction by enabling more complex designs, improving communication and coordination between stakeholders and ensuring the structures are built to a high quality.

Prefabrication and modular construction can improve construction efficiency and reduce costs in part due to their production line nature. Like factories, the prefabrication companies focus solely on these tasks, and will typically produce the same product multiple times to be shipped to different construction sites. The repetitive nature of the tasks enables them to work more efficiently than an on-site tradesperson who would have to tailor his approach to the worksite in question. This method also enables a reduction in material costs and wastage as they can purchase materials in larger quantities, thereby reducing the cost per piece, and can use any surplus for the next project, thereby reducing waste and the cost associated with waste.

Autonomous machinery can optimize the performance of repetitive tasks such as those involved in the prefabrication and modular construction methods. Both off-site in the specialised facility, and at the construction site, autonomous machinery such as robots and cranes can perform tasks in an efficient, consistent and reliable way. The use of these machines can reduce the time to perform tasks, reduce the risk of damage to building components and other equipment, reduce the risk of workforce injuries by distancing staff from potentially dangerous activities and can ultimately enhance the facility's capacity. All of these will result in cost savings. Increasingly, artificial intelligence (AI) can also be used to undertake more complex tasks.

By combining these construction methods with an effective modelling tool, engineers can access cost savings of 20% in comparison to traditional on-site building construction and can reduce the time required to construct by up to 50%[1]. This is as a result of increased efficiency in fabricating components, a reduction in costs associated with design errors and poor communication, minimizing material waste, labour and rework costs and improving overall scheduling to eliminate clashes or unforeseen issues.

The construction industry is one of the most dangerous industries for workers[2] due to risks associated with working at height, with machinery and heavy materials, and trip, slip and fall hazards. The improvement in worksite safety is a priority across industries. Prefabrication and modular construction can improve conditions for workers and reduce risk by enabling much of the fabrication of components to be undertaken off-site. Therefore, much of the dangerous work is performed in a controlled environment that is specifically designed to enable safety (e.g. permanent scaffolding, tools and equipment kept in a central location which is easily accessible, eliminating the need for workers to work at height on site). Additionally, with the pre-fabrication and modular construction techniques, bad weather conditions which would typically affect the progress of the work on site are eliminated by working indoors. This also eliminates the safety risks associated with poor weather conditions (e.g. rain, fog, ice, wind).

The US and European prefabrication and modular construction market is estimated to be USD 130 billion by 2030 and is estimated to produce an annual saving of USD 22 billion[3]. While the adoption of these construction techniques are expected to increase in the coming years, there are some obstacles that will need to be addressed These include developing off-site warehouse facilities that are fully equipped and capable of performing this function and developing the local expertise to undertake these tasks.

Ongoing technological advancement is likely to see 4D (time) and 5D (cost) modelling functionality developed which will result in further reductions in costs and increases in efficiency. 3D printing could also be utilized for construction which would further reduce any errors associated with human intervention (*see also the 3D Printing use case).*

VALUE CREATED

Improving efficiency and reducing costs:

- Reduce the cost to construct by 20% and construction time by up to 50%[4] and therefore reduce the time required for tradespeople to be on-site.
- Reduce the operations costs by reducing maintenance requirements due to the improved quality.
- Reduce the cost of materials by purchasing in bulk thereby accessing materials at a cheaper per unit cost and standardizing the prefabrication process to enable optimized use of the materials to minimize wastage.

[1] "Modular Construction: from Projects to Products", McKinsey, Accessed 14 May 2020.
[2] "Improving Construction Safety with Prefabrication and Modular Construction Technology", Connect and Construct, Accessed 12 May 2020.
[3] "Modular Construction: from Projects to Products", McKinsey, Accessed 14 May 2020.
[4] "Modular Construction: from Projects to Products", McKinsey, Accessed 14 May 2020.

- Reduce the cost of material waste further by using surplus material on a subsequent prefabrication project.

Enhancing economic, social and environmental value:

- Minimize errors by utilizing BIM modelling to detect errors in the design phase and by enabling prefabrication to be exact based on an accurate 3D model, therefore ensuring that components will fit together once on-site.
- Improve on-site safety for workers by eliminating many of the hazards associated with on-site construction and reduce safety risks further by performing prefabrication off-site in a purpose-built facility which eliminates the need to work at height, is impervious to weather conditions, and has a fixed controlled layout.
- Improve quality of build by undertaking efficient processes in a controlled off-site environment and utilizing better scheduling that reduces clashes and unforeseen issues and reduce the number of schedule changes as a result of errors.
- Infrastructure can be moved or added to, to be more resilient to changing urban or suburban environment and other unforeseen changes.
- Enable individualisation and customisation including selecting elements like the interior finishes, façade, materials and layout. When scaled to large public or private projects, the possibilities for customization to develop a unique structure are almost endless. For example, the Indian city of Vijayawada will include a high-rise apartment in which residents can select prefabricated modules from a catalogue to be inserted into the structural frame. The Google HQ building is being designed to emphasize how modular architecture is about customization rather than uniformity.

POLICY TOOLS AND LEVERS

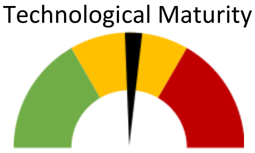
Legislation and regulation: Quality certification standards and warranties will be required to give customers confidence in the quality standard of the method. Regulation concerning the transportation of modules can restrict the size of the modules that are able to be transported from the facility to the work site by road. This therefore restricts the scale of the project that can be undertaken. Governments should examine their building codes to drive efficiency across geographic regions and enable faster approval processes by approving designs and production processes rather than requiring inspections for individual sites. Governments can encourage these forms of construction by introducing targets or incentives (as well as sustainability incentives) for public projects to involve off-site manufacturing.

Effective institutions: By partnering with developers and public authorities, manufacturers can ensure an ongoing pipeline of projects. This collaborate will also enable manufacturers to standardize their products in direct response to customer input.

Transition of workforce capabilities: Prefabrication and modular construction will disrupt the existing construction eco-system. This will affect multiple stakeholders including manufacturers, developers, construction firms, investors, and the public sector. Modular manufacturers will need to invest in building skills and expertise including capabilities in design, operations and digital technologies. Partnerships with developers, construction companies and lending providers may be required as existing talent is limited. The ongoing training of the workforce will be essential to ensure manufacturers stay competitive compared to other industries and are able to scale up in response to demand.

Funding and financing: Industries should determine whether the expected cost saving outweighs the capital investment. Public and private investment is necessary, with major private investors (including SoftBank, Google's parent company Alphabet, and even Amazon) already having invested in prefabrication developments and builders such as Katerra, RAD Urban, and Factory OS.

IMPLEMENTATION

Ease of Implementation 	Prefabrication and modular construction have long been used in the construction of residential housing, particularly in Europe and Asia. In countries like Sweden, these techniques account for 70% of the construction industry[5]. These techniques are particularly popular in regions where severe weather can affect construction and where housing affordability and a lack of available tradespeople are issues. Similar issues affect public infrastructure projects, making the techniques suitable to be used across other sectors including transport projects. The demonstrated success of these techniques in the housing sector suggests they can be deployed across other infrastructure projects with relative ease.
Cost 	The required investments to undertake prefabrication and modular construction are not insignificant. Offsite manufacturing facilities are required, estimated to cost between USD 50 million and USD 100 million each, depending on the size and level of automation used[6]. Transportation and installation of the modules requires either an inhouse fleet of vehicles and cranes, or the outsourcing of these machines. The use of these construction techniques has the potential to reduce project costs associated with the cost of materials, waste resources, rework and delays. It can improve productivity and safety for workers. The associated lifecycle costs for the project can see reductions in energy bills and maintenance requirements.
Country Readiness 	For a country or region to provide the necessary prerequisites to enable the use of this construction method, they must have a high demand for construction across industries. This may be residential housing or other public infrastructure such as hospitals, transport hubs, schools etc. This is necessary to provide a potential pipeline to facilitate the capital investment required. As labour costs increase in response to a supply shortage in many markets, prefabrication and modular construction become increasingly cost-effective alternatives. Some areas may be inappropriate for this kind of construction due to geographic constraints such as narrow roadways which prevent the transportation of complete modules to the site or restrictive regulations that prevent the transportation of large modules by road. Alternative transport methods may need to be investigated (e.g. by air) or designs may need to be tailored to suit these constraints. The cost of labour will also affect how cost-effective these types on solutions will be.
Technological Maturity 	The extent of the efficiency gains that prefabrication and modular construction can provide will be dependent on several factors including the technologies implemented in conjunction with the manufacturing process. By digitizing the sector, companies can harness that data to enable more efficient processes, and this can enable just-in-time delivery to sites, as the storage of large modules or components at the facility is not cost effective. Should the facility utilize automized technologies and automated cranes be used on site, there will be considerable planning required to ensure they are effective. These technologies are being employed in other sections and are showing noticeable improvements in productivity.

[5] "The Future is Prefabricated", University of Melbourne, Accessed 29 May 2020.
[6] "Modular Construction: from Projects to Products", McKinsey, Accessed 14 May 2020.

RISKS AND MITIGATIONS

Implementation risk

Risk: The market is currently fragmented and unstandardized. Existing operators are small and have limited experience, which has resulted in high lending rates and a high risk of bankruptcy should demand diminish. For the customer, due to the reduced project time, payment could be required upfront rather than staggered over the project term.

Mitigation: As the industry continues to develop and companies can prove their sustainability, it is likely lending in this area will be able to provide access to more cost-effective capital. Business models that consider customer financial restraints will need to be developed that find an appropriate balance between upfront payment and more staggered payments, which is more customary in construction. This may be particularly relevant for public infrastructure projects in which funding may be staggered in line with budgets.

Social risk

Risk: Public and government perception that prefabricated structures are poor quality cookie-cutter solutions may linger. This could discourage individuals and local authorities from exploring this option.

Mitigation: The benefits associated with the method should be emphasized including the reduction in capital and operating costs as well as potential sustainability improvements.

Safety and (Cyber)security risk

Risk: Where automated machinery is utilized there is a risk that the system could be hacked due to cybercrime or sabotage. This could result in damage to products or other machinery as well as other damages.

Mitigation: Organizations should ensure their systems are robust to eliminate the risk of cybersecurity breach. Furthermore, governments should set legislative frameworks to outline the requirements of these systems to repel cybersecurity attacks.

Environmental risk

Risk: The transportation of modules from the facilities to the construction sites at present is performed by large trucks on roads. This contributes carbon emissions to the environment and can also produce congestion due to the slow-moving vehicles, and difficulties moving through the road network. This would further increase emissions associated with other vehicles in traffic.

Mitigation: Where possible, prefabrication should occur as close to the construction site as possible. In future, developments in transportation should be explored that may enable the transportation of modules by energy efficient road vehicles, or potentially by aerial vehicles.

EXAMPLES

Example	Implementation	Cost	Timeframe
Melbourne Level Crossings Removal Project	Prefabricated beam segments were used to build a new elevated rail system over a train line whilst enabling train services to continue to run.	The cost of removing 50 level crossings in Melbourne estimated to be at least AUD $8.3 billion.	The project was announced in 2016 and it was estimated to be operational by 2018. Prefabrication was used to help meet this strict deadline.
Nunawading Train Station, Victoria	The components of the station were fabricated offsite.	The total project (including elimination of the railway level crossing in Nunawading and upgrade of Nunawading station) cost was AUD 140 million.	The installation of Nunawading station was completed entirely overnight during the nominated shutdown period to minimise disruption to the station operation.

Modular Bridge, Germany	Pilot project to replace existing bridge in the North Rhine-Westphalian with a new bridge system using modular and prefabrication construction techniques. The system was designed to keep construction-related traffic disruption to a minimum.	The system was designed so that the existing foundations could remain in the ground reducing the need for lengthy and potentially costly demolition and complex earthworks.	Cut construction time by more than half, down to sixteen weeks from an initial estimate of about twelve months.
Micham Railway Station, Victoria	Modular prefabricated construction was completed offsite.	The total project (including elimination the railway level crossing at Mitcham and upgrade of Mitcham Station) cost was AUD 192.	The construction of the whole project started in early 2013 and completion was due mid-2014.

CONTACT INFORMATION

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