Modern Methods of Construction: Defining MMC Business

APRIL 2022

Construction Professionals

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About Construction Professionals Skillnet

The Construction Professionals Skillnet aims to support the development and growth of construction businesses by working with them to identify and address their skills needs and through the provision of construction industry specific training and development solutions.

Construction Professionals Skillnet provides funded training solutions to enhance the skills in the construction industry by:

- offering value for money courses and programmes that are of interest to those in the industry
- sourcing and providing some funding for relevant in-house courses
- offering networking events

Rialtas na hÉireann
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Project Ireland
2040

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Foreword

By Tara Flynn

Chairperson of Construction Professionals Skillnet/Director Paul Flynn Construction

The construction sector, along with many others, is currently experiencing challenges to labour supply. As a result of Covid-19 many projects are behind schedule with new projects continuing to come on stream, imposing pressures on the sector. Also, the requirements of Project 2040, Housing for All and the recently announced Retrofit programme, increase the demand for competent people. In essence the resources and capability required to deliver on these ambitious targets is a challenge to the sector. It is estimated that an additional 112,000 people are required to join the industry over the next 10 years.

According to recent research into Modern Methods of Construction (MMC), conducted by **McKinsey & Company** (2019 and 2020) *"Multiple factors determine whether a given market is likely to embrace modular construction. The two biggest determinants are real estate demand and the availability and relative costs of skilled construction labour. In places such as the US West Coast, the southern part of the United Kingdom, Australia's East Coast, and Germany's major cities, labour shortages and large-scale unmet demand for housing intersect, making this model particularly relevant."* McKinsey & Company: (2019) Bertram, N., Fuchs, S., Mischke, J., Palter, R., Strube, G. and Woetzel, J. (2019). **Modular construction: From projects to products.**

While Modern Methods of Construction doesn't necessarily impact the amount of labour required, it certainly can impact the speed at which construction can be completed. It involves moving from on-site construction to off-site pre-fabrication and so is moving more towards a manufacturing model of business than the current construction model. As well as reducing the delivery time there are many other benefits to using MMC, such as improved safety performance and reduction in waste. However, an additional skillset is required throughout the supply chain to be able to deliver using these methods.

This report looks at the two models of business and examines what skills are required by the workforce in this new model and where the gaps in provision to meet these needs are. The report makes a comprehensive set of recommendations for construction businesses, policy makers and training and education providers.

The Construction Professionals Skillnet looks forward to working with the construction off-site manufacturers, policy makers and training and education providers in developing relevant solutions to address the skill gaps, enabling the sector to meet the Government's ambitious targets, as well as commercial requirements.

Tara Flynn
Chairperson of the Construction Professionals Skillnet.

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About the Report

Modern Methods of Construction (MMC) describes an approach to constructing buildings using methods such as off-site manufacturing, modular construction panels or light steel framing, structural insulated panels or cross-laminated timber. Off-site manufacture minimises environmental impact and disruption on-site and products can be more easily tested to the relevant standards which significantly increases product improvements including sustainability and energy efficiency.

The Irish construction industry has been relatively slow to choose the MMC option since the sector is set up to operate in traditional site-based processes. The overwhelming ask, from both investors and those in the off-site manufacturing sub-supply chain, is certainty. From the top, investors and clients need certainty of integrity, performance, and capacity. From the bottom up, the supply-chain wants certainty of demand and a delivery model that supports the design, procurement, co-ordination and funding for a manufacturing led approach.

The implementation of MMC requires both a different business model and a different skill set to traditional construction.

This report proposes to identify the new construction sector business model necessary for the effective implementation of MMC and the related new roles and skills required to perform effectively. This allows the sector to improve its productivity and meet the needs of the Irish National Development Plan (NDP) 2021 and Housing for All (HfA) strategy. While focusing on MMC it will also necessarily involve digital transformation and sustainable construction as these are intrinsically linked with the effective implementation of MMC.

Section 1:

Objectives of the Report

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The primary aims of this study and report were to present the new business model necessary for the effective implementation of MMC, identify the related roles and skills required to carry out MMC and identify the gaps in training and educational provision.

More precisely the objectives of the report are to:

1. Carry out a Value Chain Analysis of the current construction business model.
2. Propose the future Construction Value Chain Map for Modern Methods of Construction (MMC).
3. Summarise how MMC is impacting the Irish and international construction sectors.
4. Determine the implications of MMC on the roles and skills required to perform effectively in the sector.
5. Propose recommendations to construction employers to address the challenges created by using Modern Methods of Construction (MMC) in relation to careers and skills
6. Propose recommendations to education and training providers when addressing the future skills requirements of the construction sector.

Section 2:

Research Methodology

Section 2: Research Methodology

The delivery approach for this project had five stages, each with its own unique activities and deliverables, which aimed to provide a robust report. The report aims to identify the new construction sector business model necessary for the effective implementation of MMC and the related roles and skills required to enable the sector to effectively implement MMC, improve its productivity and meet the needs of the National Development Plan (NDP) – Project 2040 and Housing for All.

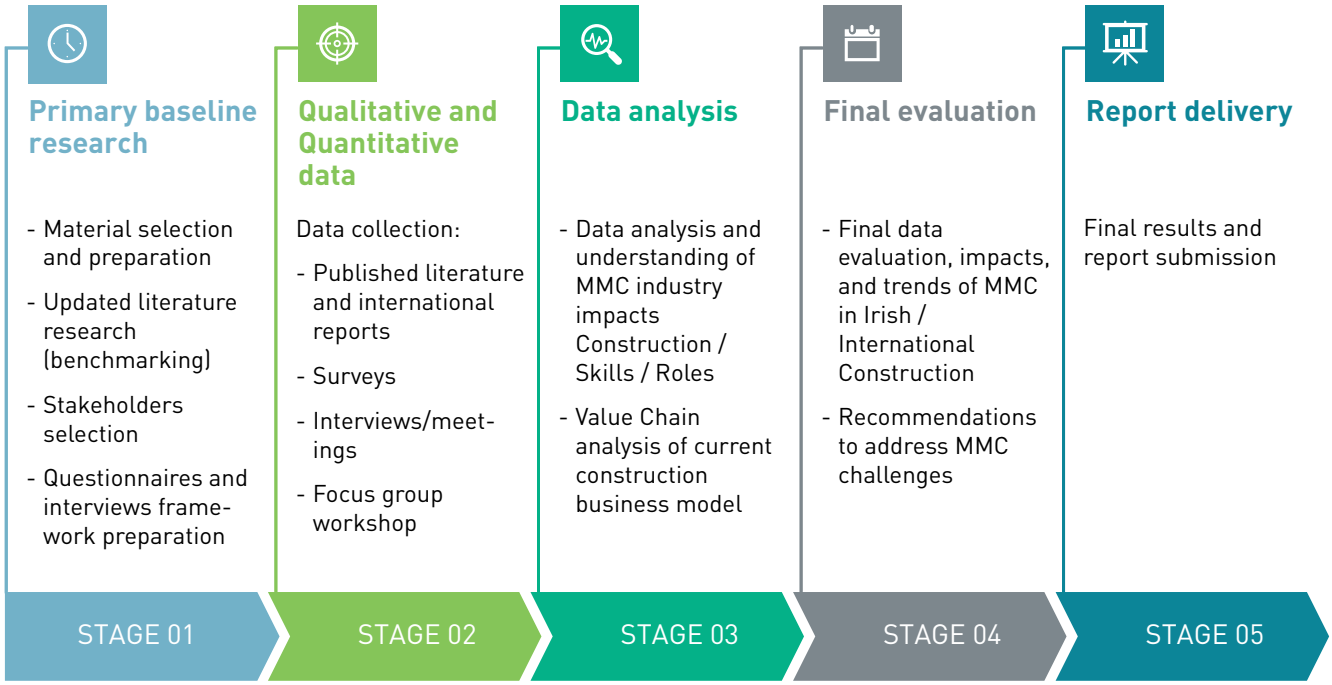


Figure 2.1: Research Stages

This investigative study was conducted using a combination of primary and secondary sources of information, gathered from October 2021 to January 2022, using both quantitative and qualitative data. In summary, these include:

- Desktop and literature review research to provide insight into international and national trends regarding the uptake of MMC, its impact on the sector and if any new or different skill requirements were already identified.
- A survey completed with key Irish construction stakeholders. The survey was conducted to gather their views on the importance of MMC for the construction sector in Ireland, the impact it can have and to identify gaps in training and education provision for the skills required from their perspective.
- Interviews with off-site manufacturing companies based in Ireland, which included in-depth discussions with industry representatives involved heavily in Modern Methods of Construction (MMC), to obtain their current opinions and skills requirements.
- A virtual focus group workshop was carried out with twenty-seven MMC industry representatives to discuss and establish their thoughts on the future skills needs for MMC within the construction sector and what they believed will be the future business model for MMC in Ireland.

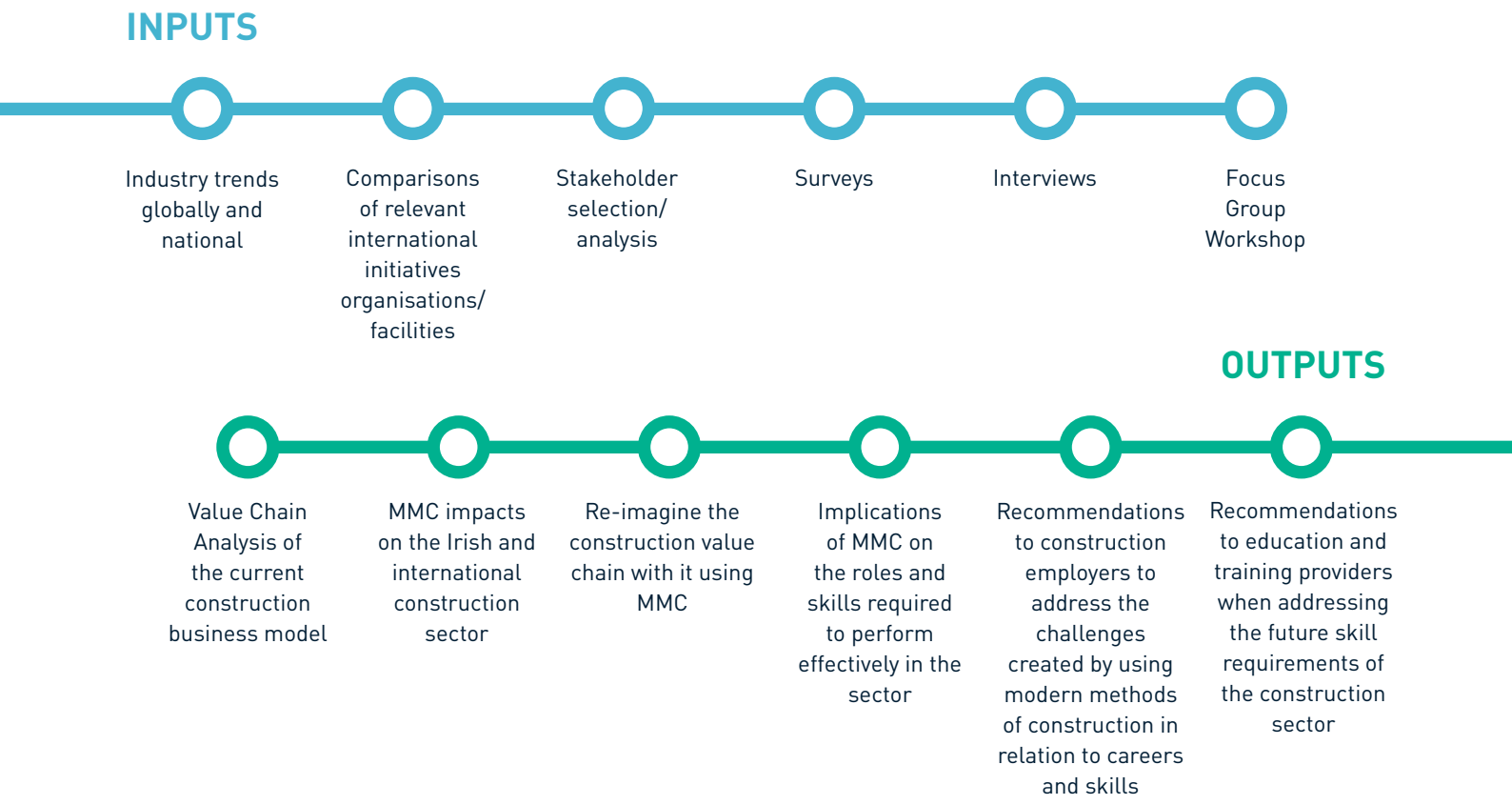


Figure 2.2: Report Inputs and Outputs

Destop & Literature Review research

A detailed desktop and literature review was conducted. However, the availability of data on Modern Methods of Construction and the related skill requirement is limited. To manage the data gathered, the report adopted a thematic analysis approach based on the original research objectives.

Survey

The survey was sent to experts with extensive knowledge and delivery experience in the MMC field here in Ireland. The aim of the survey was to ascertain the current and future skill needs in the MMC sector. It was sent to over 150 people who have MMC knowledge and experience. They were contacted directly by email. There were 52 responses, equating to a 35% response rate.

The survey questions can be seen in Appendix 1. The responses to the survey acts as the baseline for the MMC skills needs analysis, which was further validated against both the OSM interviewee responses and additional inputs received during the MMC focus group workshop.

Number of years' experience with MMC

Over forty percent (42.3%) of the survey respondents had 10 years' experience or more in MMC, supporting Irish engineering and construction clients and design teams. This shows that the MMC sector has been established for more than ten years in Ireland. However, from the interviews, it has been ascertained that the first commercial evidence of MMC in Ireland was in 2008 (eight hundred metres of the Pier E platform in the Dublin Airport Terminal 2 was produced off-site). Some companies were involved in the early 2000s in MMC processes but to a limited extent and not to the scale that they now operate.

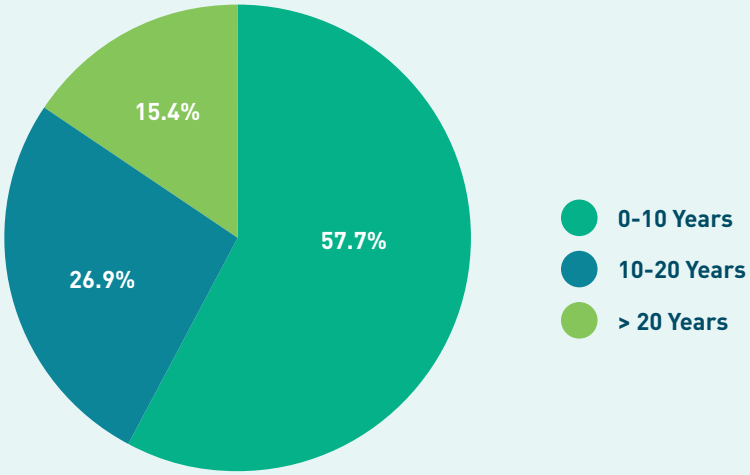


Figure 2.3: Number of years of professional experience with MMC

Business Sectors Supplied

To identify the sectors active in using MMC, respondents were asked to identify the business sectors for which they provide MMC solutions.

Please identify the business sectors that you are involved in with Modular Construction/Off-site fabrication.

Construction business sectors involved with Modular Construction/Off-site fabrication

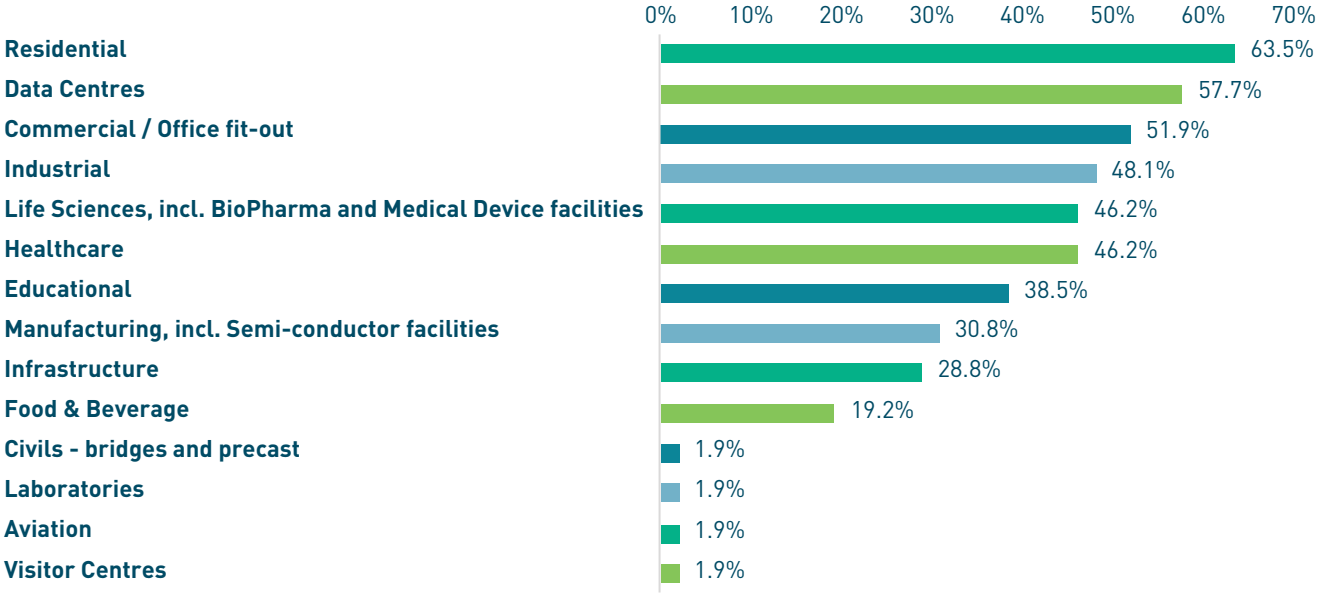


Figure 2.4: Business sectors supplied

It is not surprising that the industrial, life sciences, data centre and semi-conductor industries apply Off-site Manufacturing and Modular Construction solutions to their projects, because they were the first adopters of MMC solutions (CIF MMC Report, 2020). MMC solutions are also being provided to the residential, commercial offices, healthcare and educational sectors, with laboratories, aviation and visitor centres using MMC solutions less than other sectors.

Number of employees

11.5% of respondents worked in companies with fewer than 10 employees, 19.2% in companies with between 11 and 50 employees, a further 19.2% in companies with between 51 and 249 employees while 50% of respondents worked in companies employing over 250.

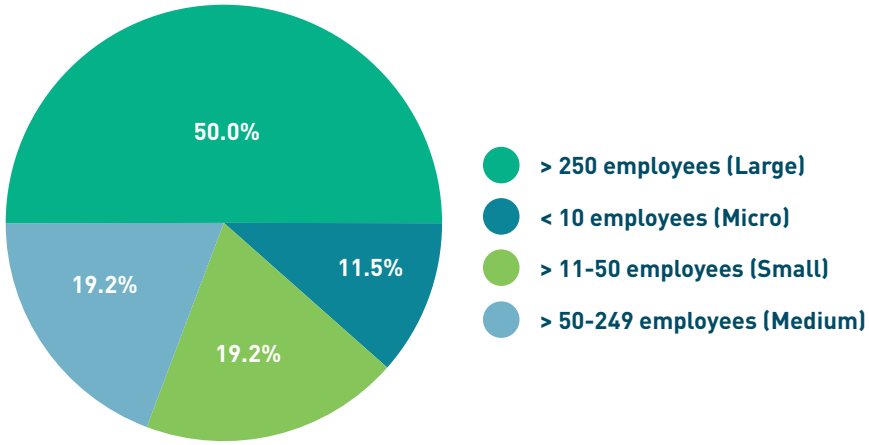


Figure 2.5: Company size

Annual Turnover

The annual turnover of the companies surveyed is shown to the right, showing 13% of respondents' companies had less than €1m in turnover, 15% had between €1m and €10m, 19% had between €11m and €50m and 52% had a turnover of more than €51m. When cross tabulated the employee numbers and annual turnover broadly correlate, in other words, the higher the turnover of the company, the more the employees.

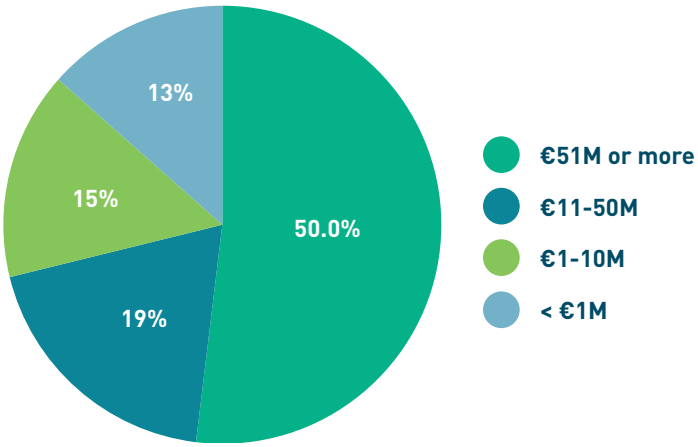


Figure 2.6: Annual Turnover (most recent) (€ millions)

Interviews

The OSM providers interviewed were chosen to ensure a diverse selection of companies that utilise off-site manufacturing with modular solutions inputs. They were selected from a database of over one hundred Irish indigenous OSM companies with fabrication facilities located here in the country. They were selected so as to represent MMC regionally, sectors supplied to (e.g. data centres, residential, life science facilities, etc.), types of solutions offered and duration providing such solutions, thus offering a good cross section of the sector.

The table below shows the location, maturity and specialisms of the OSM providers interviewed.

Off-site Manufacturer	County	Year started MMC	Specialism
OSM Provider #1	Galway	2018	2D and 3D Modular solutions
OSM Provider #2	Cork	2006	2D and 3D Timber Frame solutions
OSM Provider #3	Tipperary	2017	2D and 3D Modular solutions, with a dedicated Modular Housing division
OSM Provider #4	Carlow	2006	MEP Sub-assemblies and Modular Skids, including fully-fitted out Modularised Plantrooms for clients
OSM Provider #5	Cavan	2016	3D Modular solutions, particularly for the Residential sector, with Modular Housing capabilities
OSM Provider #6	Cavan	2020	Modular roofing and cladding solutions for the Engineering & Construction sector

Figure 2.7: Overview of OSM Providers Interviewed

Focus Group

To validate the findings from the survey and interviews a focus group workshop was held in January 2022.

The focus group was made up of the members of the CIF MMC Working Group. These people are professionals of the Irish construction sector who are currently contributing to Irish research and development of MMC, Modular Construction, BIM and Sustainability, whilst they are also active in providing MMC solutions and MMC designs to clients in Ireland and abroad. Some are also Off-Site Manufacturing (OSM) providers. The group therefore represents a good cross-sectional mix of people in the Value Chain of MMC. See Appendix 3 for full list of focus group participants.

Section 3:

Research Findings and Discussion

Research Findings and Discussion

This section presents the results of the data gathered in the research phase of the project. Initially an overview of Modern Methods of Construction and its current position in the Irish construction sector is presented. The traditional Value Stream Map of the construction is then detailed.

Each of the six Off-site Manufacturers visited and interviewed provided a detailed overview of their current Value Stream Maps for pre-fabrication and from these similar Value Stream Maps an anticipated future Value Stream Map incorporating Industry 4.0 techniques has been drawn, which supports the re-imagined future roles, functions and skillsets needed for MMC.

The below discussion presents comprehensive responses, findings and trends from this data gathering exercise which are used to formulate an effective set of recommendations, for further action, to meet the current demands and further implementation of MMC within Ireland. These recommendations will help to shape the education and training provision which is needed to upskill and reposition the current architectural, engineering and construction workforce to meet the opportunities that will arise from further adoption and implementation of MMC.

Overview of Modern Methods of Construction (MMC)

What is MMC?

MMC is an umbrella term for a general group of different types of construction which involves significant portions, or all, of the building being manufactured in a factory setting and joined together on-site. It encompasses modern construction technology and methodologies that improve productivity, particularly off-site construction. Industry terminology used to describe MMC is as follows: Pre-fabrication, Off-site Manufacturing (OSM), Off-site Assembly (OSA), Off-site Construction (OSC), Design for Manufacturing & Assembly (DfMA), Modular Construction (both 2D and 3D modules), Modularisation, Smart construction technologies or processes, i.e. 3D printing or additive manufacturing, 'plug and play' modules, etc. These terms are often used interchangeably.

It should be noted that MMC is a rapidly evolving approach to construction, and that the forms of construction in each of the different MMC categories may change over time, as the off-site manufacturing sector innovates further.

MMC spans all types of pre-manufacturing, site-based materials and process innovation. The term 'pre-manufacturing' encompasses processes executed away from the final workface, including in remote factories and near site or on-site 'pop up' factories. The pass test is the application of a manufactured led fabrication or consolidation process in controlled conditions prior to final assembly/installation. On-site 'workface factories' are included in the MMC Category No. 7 definition (see Figure 3.1 below).

The definition framework identifies the following seven MMC categories:

- **Category 1** – Pre-Manufacturing - 3D primary structural systems
- **Category 2** – Pre-Manufacturing - 2D primary structural systems
- **Category 3** – Pre-Manufacturing - Non systemised structural components
- **Category 4** – Pre-Manufacturing - Additive manufacturing and/or 3D printing
- **Category 5** – Pre-Manufacturing – Non-structural assemblies and sub-assemblies
- **Category 6** – Traditional building product led site labour reduction/productivity improvements
- **Category 7** – Site process led labour reduction/productivity improvements

A summary of the different categories of MMC can be summarised below:

Figure 3.1: Category Definitiion. (MHCLG Industry Working MMC Group,2019)

Different categories lead to different modular solutions, therefore requiring a wide variety of MMC skills and competencies. (The MMC Definition Framework report, released in 2019 by the United Kingdom's MHCLG industry Working MMC Group, provides further details about each MMC category.)

The intention is for this MMC framework to regularise and refine the term 'MMC' by defining the broad spectrum of innovative construction techniques being applied in the residential market, both now and in the future. The framework also offers the opportunity to create more structured datasets capturing use of MMC and its performance, so enabling clients, advisors, lenders and investors, warranty providers, building insurers and valuers to all build a common understanding of the different forms of MMC.

In turn this should enable confidence building through a better evidence base using the categorisation framework as a data taxonomy including the identification of building height typologies and primary structural materials used. The MMC Definition Framework also supports the industry's ability to evaluate the different ways available of increasing the 'Pre-Manufactured Value' (PMV) of its built assets.

Why MMC?

What MMC does is to bring a production process approach to construction and reduces variability in techniques that traditionally would be performed on-site during construction projects. The move towards increased off-site manufacturing for the construction sector globally has been driven by the reduction in process variability, along with cycle-time reductions, minimisation of waste materials and greater tolerances achieved than would be realised on-site. After the onset of Covid-19 (SARS-CoV-2) pandemic came labour shortages and delays in material supply, however this has been exacerbated since the re-opening up of countries' economies. This has helped to accelerate the move towards the increased application of MMC solutions.

An additional contributing factor has been the added value benefits that mature clients have realised through applying OSM approaches to their construction projects. This is leading to more informed clients and design teams, thus increasing the understanding, knowledge and requests for further pre-fabricated solutions on projects, where feasible. Building Information Modelling (BIM) has also enabled this transformation, through greater visualisation and digitalisation of modular construction solutions and enabling the production of mechanical, electrical and piping assemblies (MEP).

There are other multiple factors that can determine a given market likelihood to embrace modular construction.

From the literature reviews, the two biggest determinants are the Built Environment demand and the availability and relative costs of skilled construction labour. This is evident in other countries around the world such as the USA, United Kingdom, Australia and Germany, where labour shortages exist. This is no different to the current construction sector in Ireland and so the large-scale unmet demand for housing, in particular, makes this off-site manufacturing model particularly attractive.

At present, labour dynamics and the supply of materials are key driving factors for the adoption of modular construction.

On a more positive note, it is anticipated that Modern Methods of Construction (MMC) will improve capabilities, through further investment in building skills and expertise by MMC companies. These companies will need new capabilities in design, manufacturing operations and digital technologies to support their development of modular solutions, to meet client demands. It will also help to foster deeper partnerships with property developers, construction companies and investors.

Competition with other industries for scarce digital talent is also going to play a part as construction moves more towards digitalisation and process improvement. The construction industry will need to train talent in order to support the shift towards off-site manufacturing, so as to remain competitive against other sectors in the demand for the same skill set. McKinsey (June 2019).

A radical shift towards off-site manufacturing may also come through a combination of increased sustainability requirements, cost pressures, construction skills scarcity, new material technology, improved industrial processes and digitalisation, as a new breed of MMC companies looks set to challenge the traditional construction value chain. With changing market environments, technological progress and disruptive and innovative solutions the construction sector will not be immune to an unprecedented rate of disruption, which has been accelerated by the Covid-19 pandemic.

Fundamental shifts and change to the construction sector will likely be catalysed by changes in market dynamics, such as scarcity of skilled labour, persistent cost pressure from capital investment and the requirement for social and affordable housing, stricter regulations for on-site activities, sustainable construction requirement and the evolving sophistication and needs of construction clients. This will help further the adoption of off-site fabrication, supported through emerging disruptions, including industrialisation and new materials, and the digitalisation of products and processes, which will shape the future dynamics of the construction industry.

The persistent scarcity of skilled labour and competing labour requirements has resulted in skilled-labour shortages that have become a major issue in several construction markets. The impact the Covid-19 (SARS-CoV-2) crisis is having an immediate effect on the construction sector, and no doubt on the labour dynamic in the long term.

Additionally, the shift towards off-site construction is seeing a much deeper integration in 2D and 3D product design such as panelised doors, windows, wall frames and fully pre-installed mechanical, electrical, and plumbing (MEP) systems. From the literature review it is anticipated that the off-site manufacturing processes will utilise BIM model data sets to a greater extent to automate their machine factory controls for increased customisation. It will be a mixture of 2D flat-pack and 3D volumetric pre-construction modular solutions that will facilitate this shift.

Using value stream mapping of the traditional method of construction versus modern methods of construction can help clarify where improvements can be achieved through clearly identifying the time-lines as well as the material, information and financial flows. While the value chains proposed below can indicate the benefits modern methods of construction can bring, it is a direct comparison between the current and future state of a specific value chain that will really highlight the benefits to be achieved.

Value Chain Analysis of the current Irish Construction business model

Definition

Value Chain Analysis (VCA) is about visualising work and aligning processes and leadership for organisational transformation. It gives organisational clarity by visualising non-visible work. It connects the process parts into a whole, with one goal, to provide higher customer value, with unbiased, fact-based insights and improvements to achieve and sustain outstanding performance (LCI,2021),(McKinsey,2020).

The first step in Value Chain Analysis is to create a Value Stream Map, i.e. the sequence of activities by the organisation to design, produce and deliver value to a customer. This helps identify the information, material and financial flows in the whole process, which helps to:

- Create a continuous improvement strategy.
- See work progress from request to fulfilment.
- Deepen an organisational strategy to make better decisions.
- Create data-driven approaches for decision making.
- Reflect work-flow from the customer's perspective.

Current State Analysis

A Value Chain is a type of business model that includes all the different activities that are needed for the project. Within the construction industry, a Value Chain is created to ensure that a project is successful from the planning stage, all the way to the completed and approved building structure. According to the respondents and a McKinsey report analysis (2020), the principal reason why the Irish construction industry has been relatively slow to choose the MMC option is that the sector is set up to operate in traditional fragmented site-based processes.

The fragmented Value Chain means that projects involve many steps and multiple companies with scattered accountability, which further complicates coordination. Additionally, skilled labour shortage, contract structures and incentives tend to be misaligned. Risks are often passed down the value chain rather than being addressed up front and players make more money with claims than by delivering quality services. Furthermore, as the construction industry is highly regulated, requiring permits and approvals for safety standards, the common use of lowest-price* rules in tenders makes competition based on quality, reliability, or alternative designs difficult and reduces space for innovation. *While MEAT (most economically advantageous tender) is used, the percentage of marks awarded for cost is usually relatively high for construction tenders.

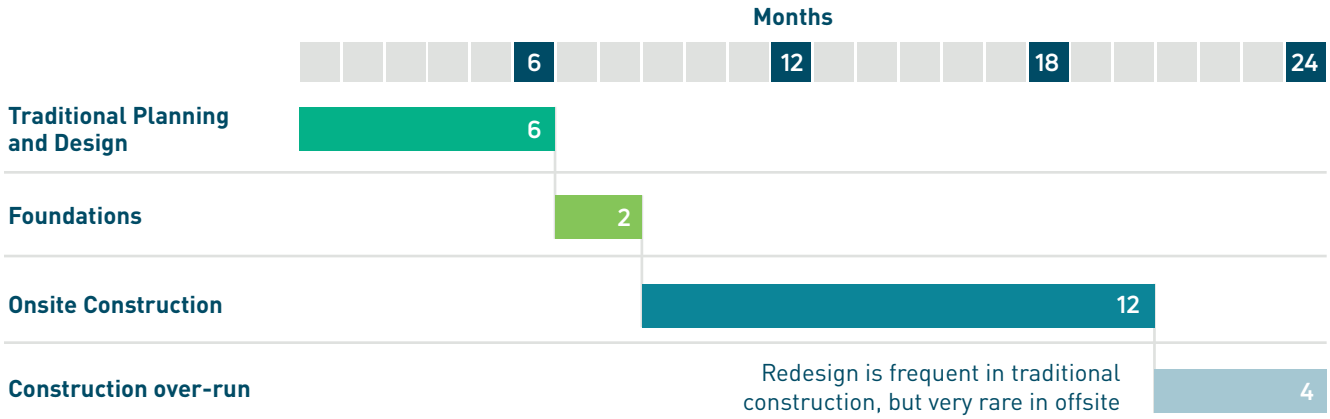


Figure 3.2: Traditional Construction for On-site Construction Activities (McKinsey, 2019)

For numerous reasons (labour shortage, increased materials costs, energy and fuel inflation, Brexit impacts on supply chains and work permits application delays) the construction industry is having a hard time building at a price point that makes sense for developers who want to meet the demand for equitable and accessible housing (RTE business, 2021)

As shown by the graphic below, the traditional construction industry is the least productive of all sectors. Almost all its processes are repetitive, waste (and cost) heavy, and labour-intensive.

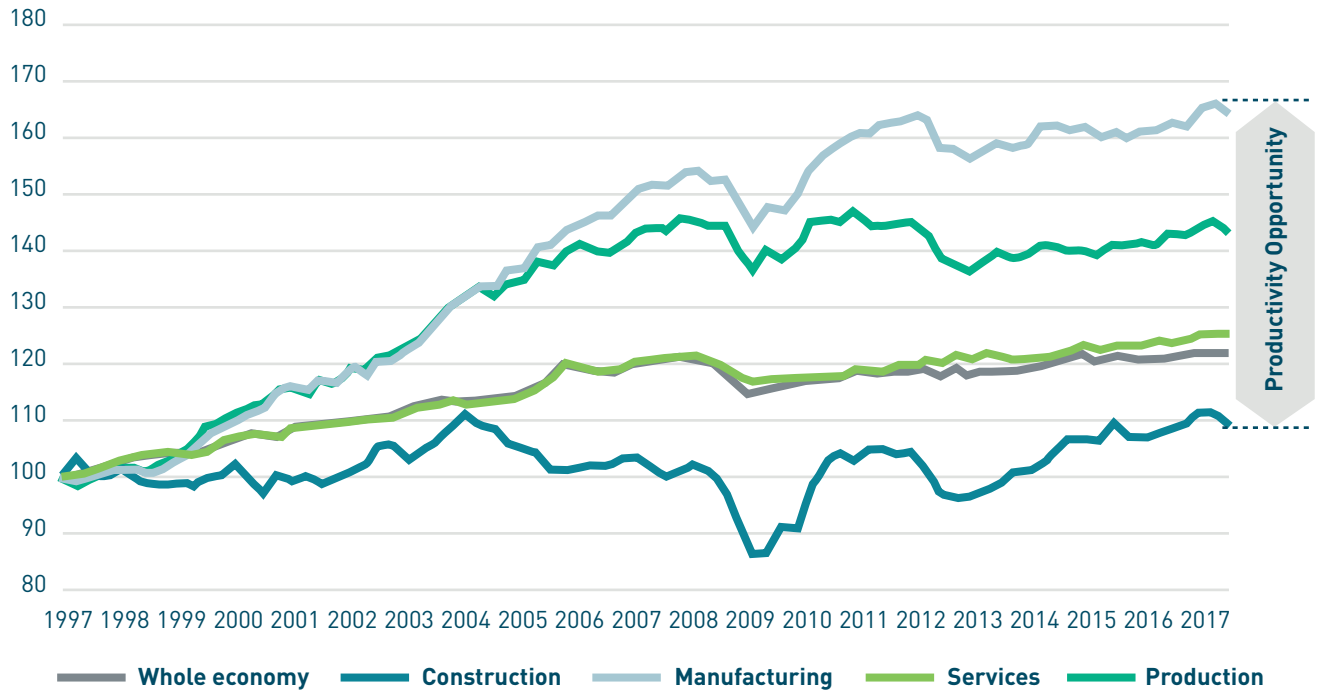


Figure 3.3: Sector Productivity (ONS Office of National Statistics UK, 2020)

In addition, the vast majority of construction companies (over 95%) are SMEs. As such, they would require significant support to be able to utilise and implement MMC, given the associated resources, retraining costs and labour shortages currently being experienced. (Ernst & Young, 2021).

Construction Value Chain using Modern Methods of Construction (MMC)

As already noted, the overwhelming ask, from both investors and those in the off-site manufacturing sub-supply chain, is certainty. From the top down, investors and clients need certainty of integrity, performance, and capacity. From the bottom up, the supply chain wants certainty of demand and a delivery model that supports the design, procurement, coordination, and funding for a manufacturing led approach.

While certainty would also benefit the traditional construction value chain, the fact that construction is on-site reduces the capacity for certainty throughout the delivery of a project, e.g. weather, consistency in workmanship, etc., and hence also reduces the capacity to minimise waste, increase efficiencies and reduce cost.

The typical Value Chain for Off-site Manufacturing/Modular Construction for residential construction is completed over 10-16 weeks depending on the type of modular design solutions used. The construction value chain using Modern Methods of Construction is more efficient than traditional construction because the work can be undertaken in parallel in a controlled factory environment, while the on-site grounds-works, foundations and building structure are being completed. The benefits of this optimisation approach are time savings of between 30-50%, which then results in associated cost-savings, since it requires less labour and interfaces on the construction site. It also results in the minimisation of process waste on-site, health and safety improvements and social and sustainable intangible benefits, due to less commuting to site by construction labour, reduced construction noise, material wastage, etc.

The figure below highlights a value chain for MMC of housing construction over 16 weeks from design, whereas traditional block and brick construction for a typical 2-storey house takes on average 32-34 weeks to complete on-site.

Figure 3.4: Greenstone.ie – Off-site Manufacturing Value Chain Process Map for Residential Modular Construction (Ref: https://greenstone.ie/?page_id=96)

There are two critical elements to this Value Chain. Firstly, to be able to set up a manufacturing process for construction there has to be certainty in demand. There needs to be a level of output required that warrants the investment in an OSM facility and the related production line/s. Secondly, the need for design freeze. Once a production line has been set up, any changes are costly and would wipe out the efficiency and cost reduction gains.

Unfortunately, there is little literature detailing the degree of effectiveness of MMC in the construction of houses, particularly in terms of time and cost benefits and even less so for more complex modular solutions. Some work has been carried out on mechanical and electrical modular assemblies, though these have yet to be published and proven.

The current leading MMC publications are from Mark Farmer, Modernise or Die (2016), McKinsey and Company reports on Modular Construction (2019 and 2020) and the Construction Industry Federation (CIF) Modern Methods of Construction reports published in 2020 and 2021. In terms of the Value Chain, these reports suggest further studies should be conducted to have a better overview of this new disruptive methodology and the off-site manufacturing value being obtained.

The main Value Chain differences regarding MMC and traditional construction are in terms of time and labour savings, resulting in productivity increases and improved tolerances in more controlled factory environments.

Future Value Chain Analysis of Off-site Manufacturing for Irish Construction

In defining the 'future' state, to develop a better MMC Business Value Stream, it is very important to reduce the handoffs, between pods and different manufacturing personnel, to eliminate easy-to-see waste streams. According to the survey and the MMC facilities interviews, the construction process is expected to work under an industrialised setup by moving from a project based to a product based approach. Based on the current practices of Irish MMC companies as well as the responses from our OSM interviews, the current complex and fragmented construction ecosystem (Traditional Value Chain) could transition to a more standardised, consolidated and integrated construction process (New Value Chain) as per the figure below.

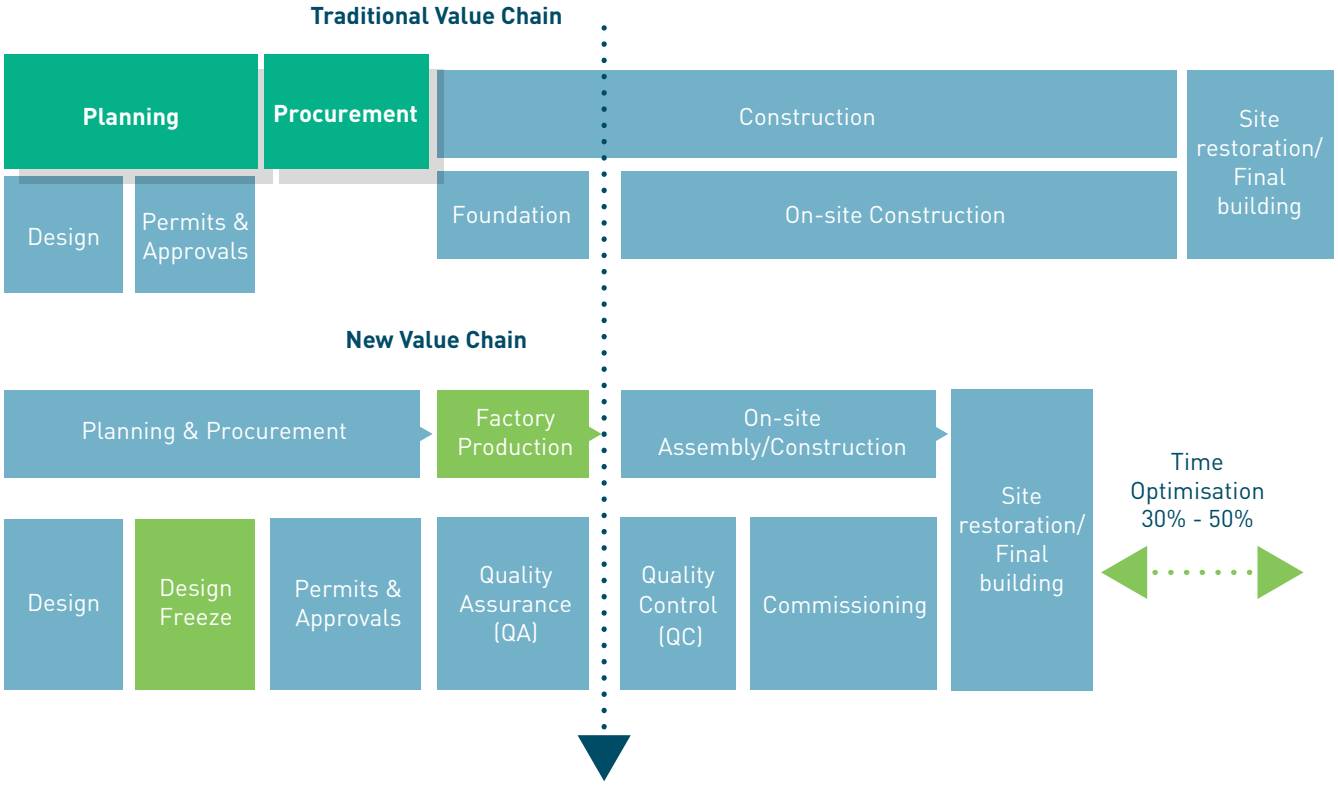


Figure 3.5: MMC Construction Value Chain – Re-imagined (the future state)

It is clear that a significant advantage over conventional on-site construction lies in the time saved because, in the traditional model, work on the building cannot begin before the foundation is completed. With MMC more work can be completed off-site while the foundations are being built and more time can be saved on-site.

A modular approach may also reduce supply chain delays as modular manufacturers typically have stronger connections with a broader network of qualified material suppliers, as well as the ability to store bulk materials compared to traditional on-site operations. It is possible to save even more by coordinating off-site and on-site operations: components of a building should be fabricated, transported and delivered to site with no delays and work men on-site ready to install and commission.

According to the OSM interviewees the key differences between the current Construction Value Chain and Modular Construction (MMC) Value Chain are:

- The need for an early design freeze since this is necessary for the production of standard and agreed modules.
- An increase in co-ordination with the client (back and forth meeting to agree the final design in advance of procurement of materials and production).
- The need for upfront payment to allow the procurement of materials and factory production – payment before delivery.

Whilst these would also be pertinent to a traditional on-site construction approach, there is less variability in a factory environment than would be encountered on a daily basis on a project site, and the production factory would not be subject to the same weather impacts and constraints, thus allowing for increased cycle-time reduction and consequently cost reductions, to increase efficiencies and productivity gains, through standardised and unimpeded lean production processes, with repetitive manufacturing steps.

The figure below summarises the Value Chain Map of MMC facilities in Ireland. It is important to highlight that depending on the MMC solution to be provided, the manufacturer may have additional steps around design, quality control or assembly. For instance, depending on the type of MMC solution to be delivered, the procurement of materials may be undertaken after the design freeze or before where the factory facility has its own materials warehouse.

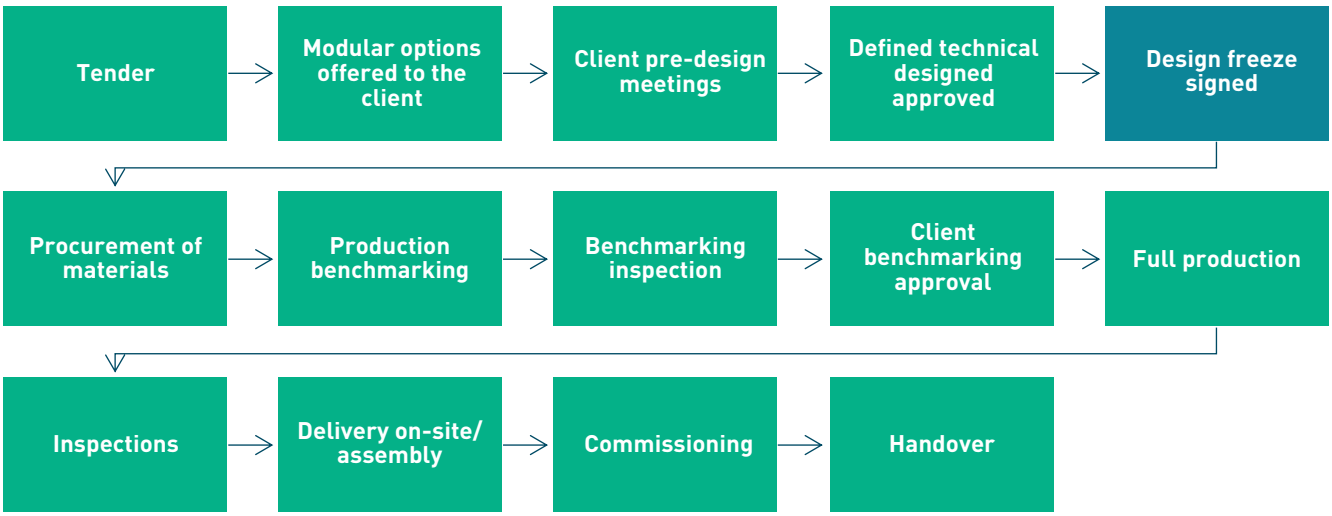


Figure 3.6: Current MMC Manufacturing Supplier Tender to Delivery Process

The off-site construction manufacturing process is far faster than the equivalent building process on-site. This is due to the enclosed and controlled factory environment, the ability to coordinate and repeat activities and increasing levels of automation. Capacity and throughput times are also impacted by the number of shifts; typically, two eight-hour shifts are used, although if the appropriate labour is found, three shifts could, in theory, be possible. Manufacturing can take place in parallel with foundation work, unlike the linear timeline of a traditional project.

Thus the MMC Construction Value Chain provides a faster and more productive option to deliver modular and infrastructural projects around the country through increased lean manufacturing and production processes.

MMC impact on the Construction Sector

According to the interviewees and the literature review, particularly as cited by McKinsey & Company, in both 2019 and 2020, MMC creates a disruptive business model, which will have profound effects on how construction projects will be delivered and resourced over the coming 10 years.

These effects include

- Construction costs and lifetime costs of the building are reduced
- Scheduling of builds that is more efficient
- Building times and costs are more predictable
- Increased sustainability

Additionally, MMC may give rise to a substantial shift of labour from on-site to off-site, which will be disruptive to the current on-site supply-chain and employment model. To maximise these new innovative and growing employment opportunities in MMC there will be a need for MMC training and educational courses to facilitate this labour market shift.

MMC is already drawing in new competitors and it will most likely create new winners and losers across the entire real estate and construction ecosystem since it will require investment in new technologies.

International Context and Competition

In many countries, MMC is still very much an outlier. But there are strong signs of what could be a genuine broad-scale disruption in the making.

Multiple factors impact whether a given market is likely to embrace modular construction. The real estate demand, the availability and relative costs of skilled construction labour and the housing crisis faced by many countries, has accelerated the demand for MMC solutions from clients (McKinsey 2019). The global SARS-CoV-2 pandemic has also impacted upon global supply-chains and thus has resulted in a shift by companies to more reliable production capacity, which has increased pre-fabricated solutions off-site for the construction sector.

The purchase of permanent modular buildings in North America increased by 51 percent in the period from 2015-2018, with total revenue growing by a factor of 2.4. In both the United Kingdom and the United States modular construction represents approximately 20 percent of total hotel construction projects (McKinsey 2020).

International competition was not seen by our interviewees as a current or immediate threat to the Irish indigenous MMC supply-chain even though it was felt that MMC, and the associated fabrication processes, are not unique or copyrightable. However, it is believed that the requirements for NSAI Agrément certification, different material selection due to the Irish weather, sectorial employment order trade labour rates, capitalisation costs to setup an MMC facility and existing Irish Building Regulations and Standards would prohibit any new entrant to the Irish MMC marketplace.

New entrants would also experience the same labour and material constraints, which are present due to the impact that Covid-19 (SARS CoV-2) virus has had on global material supply-chains.

From the interviews carried out, China appears to be the main competitive concern. They are very keen to learn and provide capital investment to Irish MMC companies. Though with barriers to entry, such as certification schemes and knowledge transfer, they have not penetrated the market too much as yet.

Labour competitiveness and hourly labour rates are seen as critical to ensure that Ireland remains competitive against European, UK and global economies that also provide Modular Construction/Off-site Manufacturing solutions.

Irish Context

Based on UN World Urbanisation Prospects report (2019), the projected average annual population growth rates between 2020-2025 cited Dublin as the 12th fasting growing city of the twenty cities assessed. More dramatically Dublin is the 4th fastest growing city compared to other European capital cities. It is estimated that Dublin will have a population close to 1.45 million people in 2035. According to the UN report, in 2050, 75% of the population in Ireland will live in urban areas further eroding the regional towns and villages. (UN World Population Prospects, 2019).

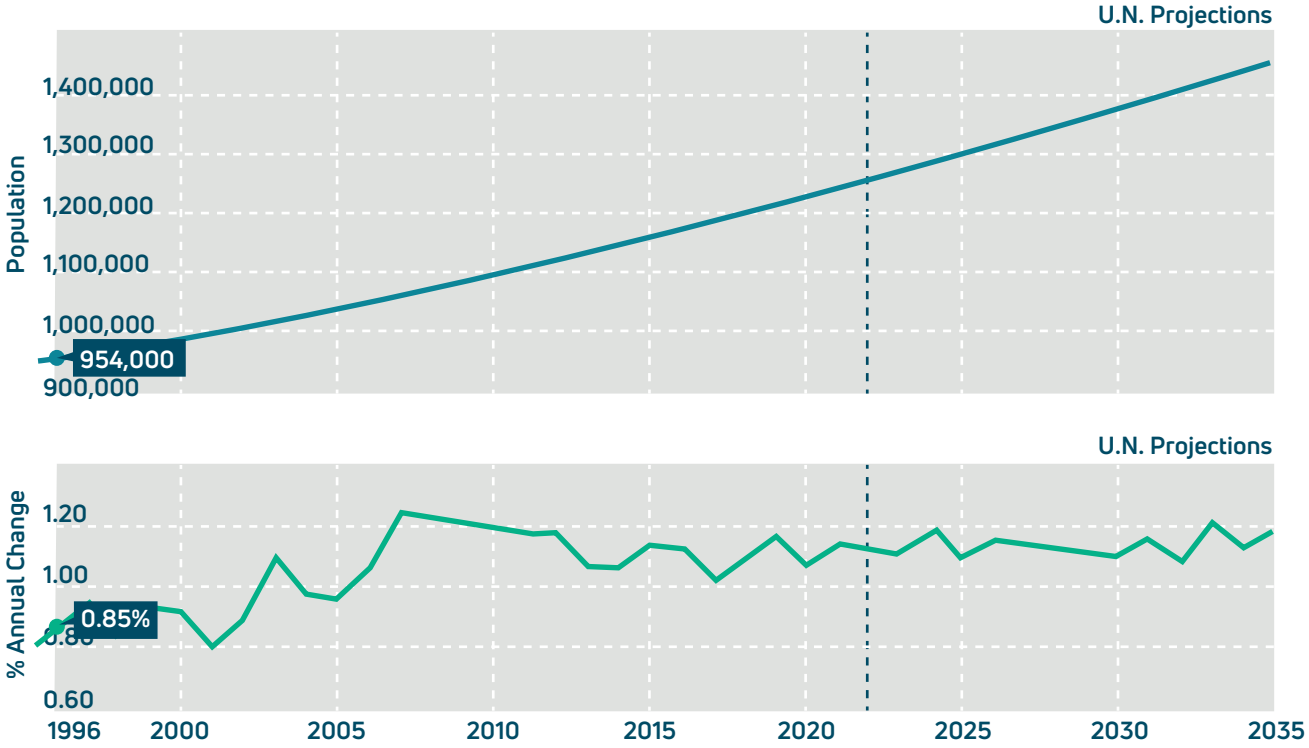


Figure 3.7: United Nations – World Population Prospects (Ref: https://population.un.org/wpp/)

The demand for houses, buildings, industrial facilities, data centres, hospitals, schools, infrastructure projects and so forth is growing and cannot be fulfilled by the present construction industry capacity. This creates space for the adoption of MMC in a variety of projects to cater for these demands since it shortens construction programmes, allows for easier upgrades in the future and optimises space usage.

To achieve a high level of energy-efficient and affordable housing using traditional construction techniques in a short period of time is a challenge, as identified in the recent CSG Innovation and Digital Adoption – Sustainability Consultation Working Group Report (November 2021). In addition, the same study has shown that there is a significant waste of material in those conventional techniques. The many benefits of MMC include a significant reduction in programme time as construction of modular units can be prefabricated off-site and indoors, external factors such as inclement weather is avoided with increased productivity, creating greater efficiencies.

Some of the rise in popularity of MMC over the last few years in Ireland is due to the potential solution that this construction method can offer to the housing crisis. Moreover, according to the OSM interviewees, the growth in the demand for student accommodation, build to rent and hotels in the country in the last five years is also a key driver. Thus, the requirement by the market for fast-tracked construction projects drives off-site construction as the realisation of the benefits of this approach is occurring in the market and the use of MMC will start to become a requirement.

The Covid-19 (SARS CoV-2) virus has also changed the view of construction professionals about MMC. Sapphire (2020) highlighted that Modern Methods of Construction is key to achieving requirements posed by the current pandemic, i.e. social distancing, less site labour and the need for efficiency. The results of a recent market sentiment survey published by Linesight stated that most designers and contractors estimated that MMC represents less than 10% of current turnover in their business. Nevertheless, due to Covid-19, 89% of designers and contractors believe that it will accelerate MMC adoption. Nearly all designers and contractors estimate that in the next three years, there will be an increase in MMC use in the industry (Linesight, 2021). Prior to the publication of this report, Cousins (2020) had already suggested that restrictions put in place to control the pandemic could be seen as an accelerator of MMC adoption. As construction sites were forced to be closed, or at least reduce the number of workers on-site considerably to comply with social distancing guidelines, the productivity of construction work on sites dropped even more. Meanwhile, manufacturing facilities were kept open.

> “The health and safety of factory environments are much greater than in construction sites.”
>
> (Irish OSM Manufacturer interviewee)

The current safety concerns are a driver for MMC adoption in projects looking to minimise the impact of site closures or reduction of productivity in project delivery.

There is a good regional distribution of over one hundred OSM providers across the country, with dedicated off-site fabrication facilities located within different regions across the country. There will be regional and local employment benefits from increased MMC adoption which is supportive of a sustainable and circular economy through a greater work-life balance for people, support of the rural economy and a reduction in commuting to the larger city locations, for on-site construction projects.

See geographical figure overleaf →

Figure 3.8: Irish OSM supplier examples. (Source – Quality Positive Limited research)

This helps support the National Development Plan (NDP) around regional employment and towards meeting sustainability requirements, in reduced transportation (of workers and materials) and accessibility costs on projects dispersed across the country.

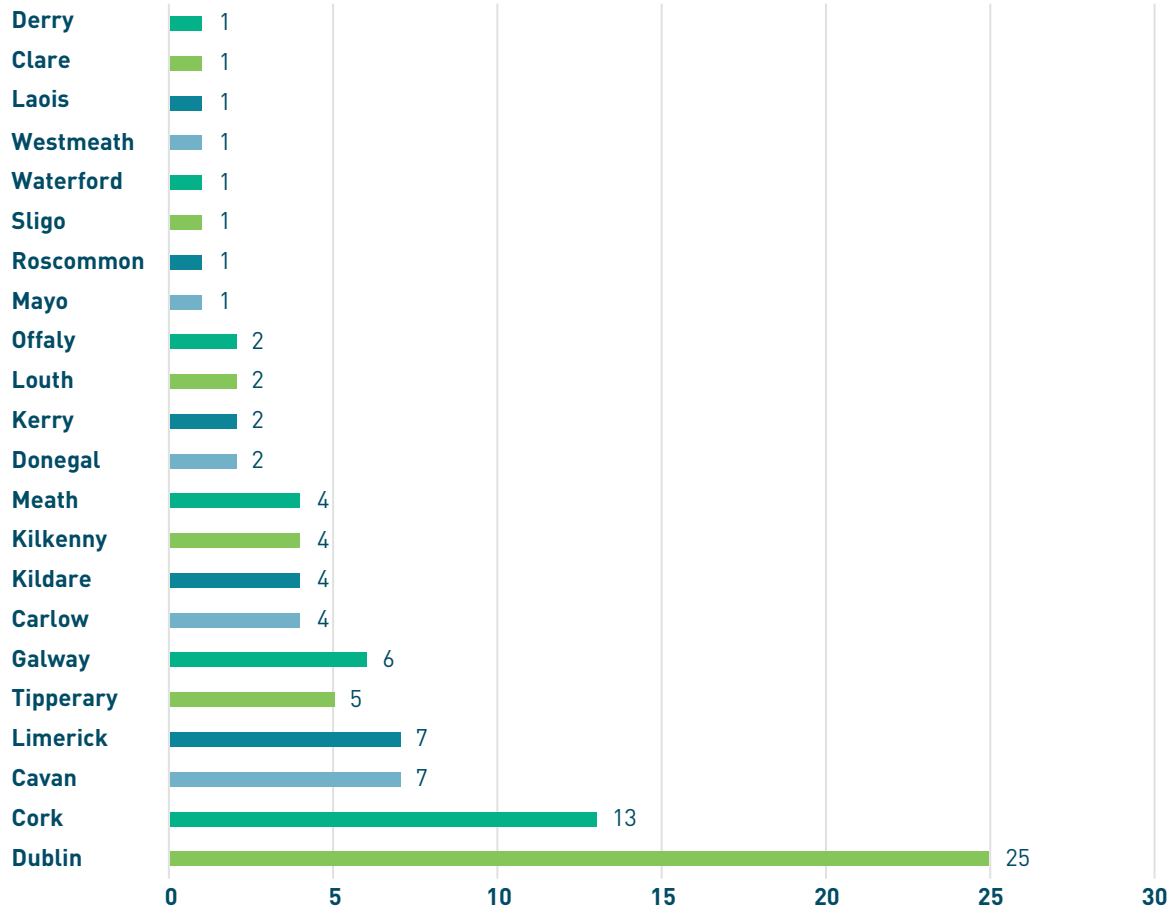


Figure 3.9: Irish OSM supplier data base 2022. (Source – Quality Positive Limited research)

Currently there are over 100 Irish Off-site Manufacturing companies with footprint facilities located around the country, manufacturing and supplying various 2D, 3D, sub-assemblies and bespoke modular solutions for Irish and International (mostly mainland European) clients. However, there are only twenty-seven MMC companies that currently provide complete housing solutions to the Irish Construction sector and thus would need to be able to scale up, due to increased volumetric demand and an increase in MMC skill sets to meet the Housing for All (HfA) 2021 strategy – Action Plan for supporting 30,000 residential units being built annually by 2030.

Current MMC Irish Supplier by sector

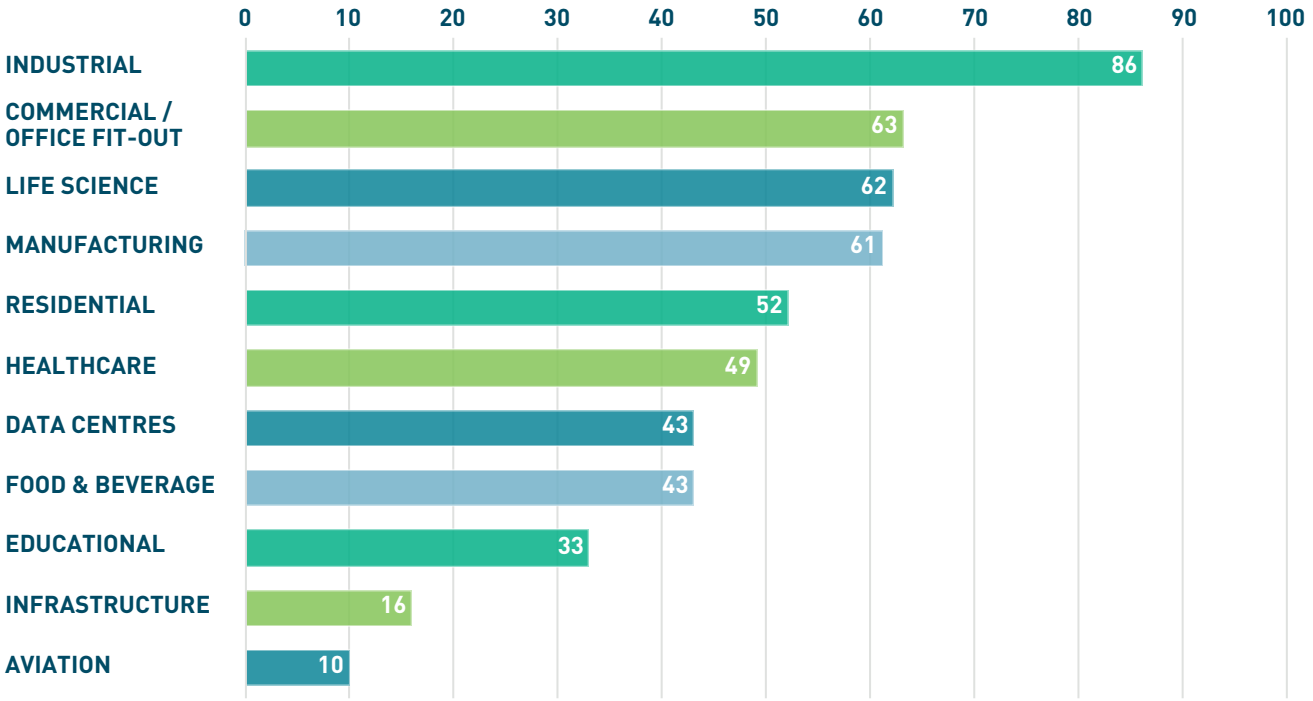


Figure 3.10: Irish OSM supplier by sector supplied. (Source – Quality Positive Limited research)

Current Irish Construction Sector Constraints

If the benefits of implementing MMC are so beneficial what are the barriers to its uptake? A recent Master's thesis (Mourão, L. B., 2021) investigated what the main barriers to MMC implementation and the further adoption of OSM in Ireland are. In this study, forty-five construction professionals were asked about their perceptions of current restraints/issues that prevent the further adoption of MMC on Irish construction projects. The results in Figure 3.11 show the key barriers identified in this research.

Skill and Knowledge	16.39%
Process and Programme	15.19%
Industry and Market Culture	14.11%
Supply Chain and Procurement	14.06%
Cost, Value and Productivity	13.66%
Logistics & Site Operation	13.32%
Regulations	13.27%

Figure 3.11: Key Irish MMC Barriers (Mourão,2021)

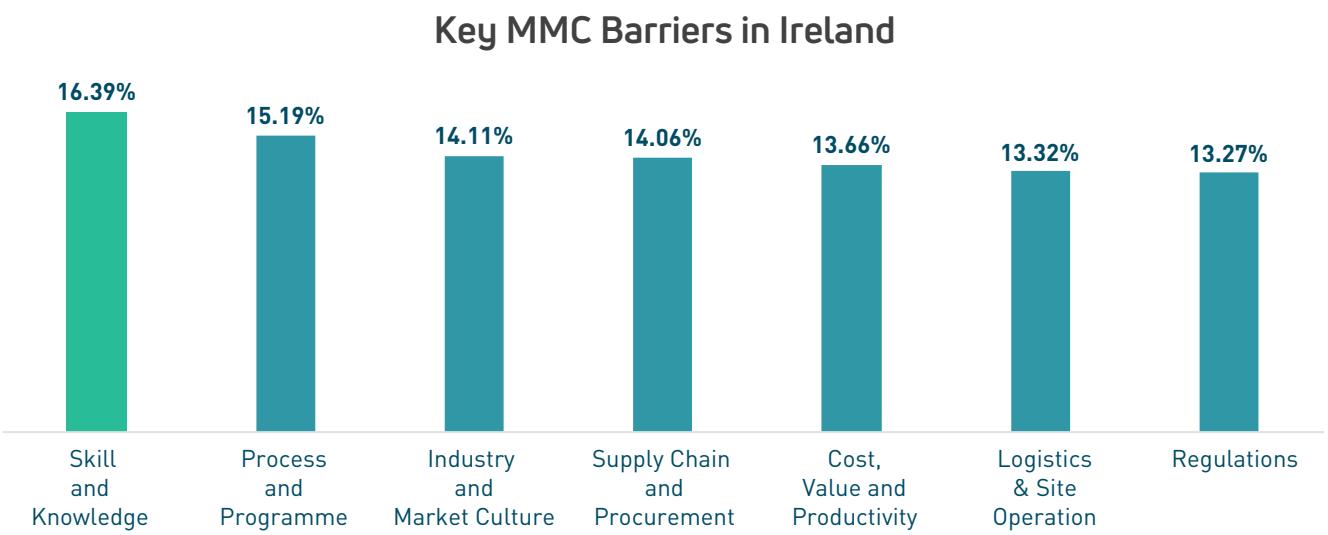


Figure 3.12: Key Irish MMC Barriers (Mourão, 2021)

Skills and knowledge were the main barrier identified. Appropriate use of skilled labour and training of the relevant sections of the workforce in MMC are essential for the successful use of off-site construction methods. Off-site construction requires higher levels of skill and flexibility in the installation workforce than that of traditional methods. In addition to the traditional skills associated with building services installations, the workers will need to cope with the changes in the production process. The manufacturing environment reduces variability in work activities and processes and increases the requirement for accuracy. Workers would need to adapt from the variety, movement and safety requirements of a busy construction site to the repetitive nature of a manufacturing environment, coupled with reduced downtime and increased productivity on the production floor.

The literature review identifies that modular construction may necessitate an increased investment in human resources, training, innovation, digitalisation, value-chain optimisation, MMC technology use and specialisation in product designs, as it requires the development and retention of in-house manufacturing expertise. In other words off-site manufacturing companies need to upskill their workforce.

In his review of the UK Construction Labour Model report: Modernise or Die (October 2016, Farmer, M.) Mark Farmer stated:

> "There is also a significant opportunity presented by the Build to Rent sector to create a cyclical and at scale demand that could underpin significant investment in innovative ways of building and the development of new skills across the industry."

With a recommendation set specifically for the UK CITB (Construction Industry Training Board) as:

> "Recommendation 5: A reformed CITB (UK) should look to reorganise its grant funding model for skills and training aligned to what a future modernised industry will need" *(in terms of Modern Method of Construction).*

Implications of MMC on the roles and skills

According to the interviewees the push for the construction industry to embrace innovation, technology and digitisation has never been so great. There is also a skilled-labour shortage, which as well as being one of the drivers of MMC is also seen as a constraint that impedes its wider adoption. This construction approach requires specific skills from designers, engineers, on-site labour, project managers, etc. The lack of knowledge by professionals surrounding this approach leads to there being a limited workforce that can develop and handle projects using MMC. The current education and training system still focuses on traditional building methods. Therefore, the development of knowledge surrounding MMC is necessary so that there will be a better understanding of it, leading to stakeholder confidence in embracing the benefits offered by this solution and adopting it on projects.

The survey, interviews and focus group workshop, along with the Off-site Manufacturing facility visits created insights to the skills gaps which Irish MMC companies are experiencing at present. It also identified their immediate MMC skill needs from an education and training perspective, that cannot be met by current provision.

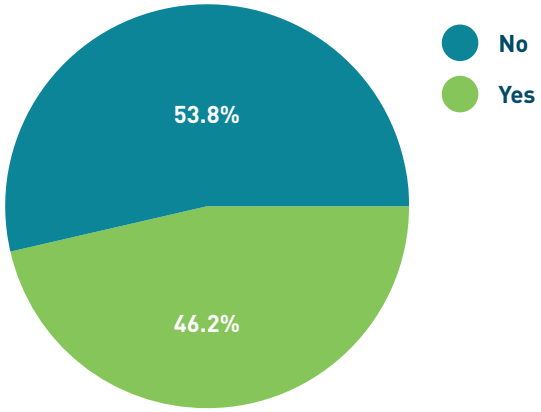


Figure 3.13: Does Ireland currently have the working skills to successfully apply MMC?

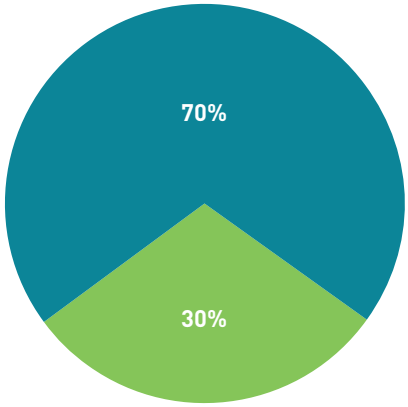
When asked if Ireland has the working skills currently to successfully apply MMC, the results confirm that there is a gap - 53.8 % of the 52 who answered this question, responded that it didn't, while 46.2% believed that the skills were available . The No response has reduced from two previous surveys, that asked the same question back in 2021 under the following research:

- Construction 4.0: An investigation of Off-site Construction in Ireland – LIT Masters' Thesis (Mourão, L.B. – August 2021)
- CIF MMC Phase 2 One-to-One Interview responses received from 29 MMC industry stakeholders

The results of both are outlined below:

Barriers that most restrain OSC adoption in Ireland	
#1	Current education and training still focused on traditional construction - (Skills and Knowledge category)
#2	Lack of understanding of the advantages of OSC - (Skills and Knowledge category)
#3	Changes after production has started are expensive (Process and Programme category)
#4	Lack of incentive to support this approach by the government - (Industry and Market Culture)

Figure 3.14: Barriers to MMC in Ireland (Mourão, 2021)



The rationale for the dramatic change in response from the CIF MMC interviews is that they that were conducted with a wider group, which included both public and private clients, design companies, main contractors, specialist trade contractors, certification bodies and off-site manufacturers. Whereas this MMC skills needs survey was targeted at specific stakeholders who are active in the offsite manufacturing sector in Ireland and who have already invested in their current MMC workforce, since they started to apply to MMC solutions. They therefore have a different perspective and deeper understanding of the needs for MMC skills and training.

Figure 3.15: Does Ireland currently have the working skills to successfully apply MMC? (Phase 2 CIF MMC Report interview responses 2021.)

MMC Roles and Skills Gap

For the survey, potential skills needs were classified into twelve groups and respondents were asked, on a scale, to agree or disagree as to their relevance to MMC performance.

The summary of results can be seen below:

MMC required Skills

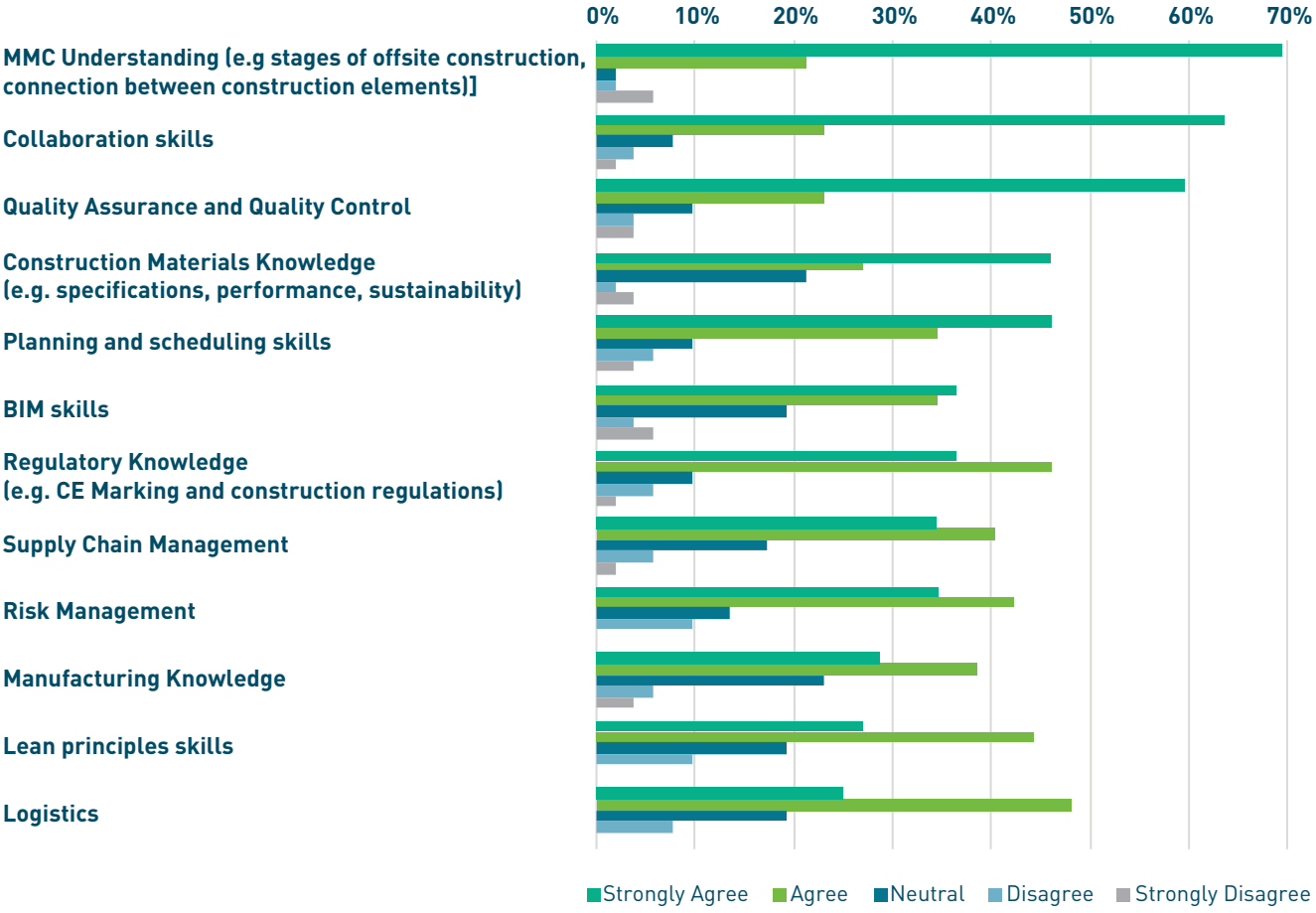


Figure 3.16: MMC required skills (Source – Research database analysis)

Nearly 36.5% (19 out of 52) of the survey respondents believe that there are no additional MMC roles and skills sets needed, other than the twelve listed within the previous question. This may reflect their current OSM maturity and was identified as an area for further exploration during the OSM facility visits and the focus group in order to validate this response.

The focus group workshop and OSM interviewees were also asked what other skills and roles were needed for MMC. The following provides a more definitive list of the MMC skill sets needed to perform within an existing OSM facility.

- Sustainability / Sustainable Construction
- Regulatory knowledge, including building regulations
- Commercial / Finance / Insurance / Contract Management (for a MMC environment)
- Product Design / Manufacturing
- Digital and Data Analysis Skills
- Interdependencies / Interfaces
- Manufacturing / Production Floor Skills
- Early Engagement / Early Contractor Involvement
- CNC (Computer Numerical Control) Operator / Rolling Machine Operator
- Innovation by Design
- MMC Supervisory Skills
- MMC Leadership / Management Skills
- Regulatory / Fire Knowledge for MMC
- Preventative / Machine Maintenance Skills
- QA/QC and Handover Knowledge for MMC
- OSM Commissioning Knowledge and Skills
- Off-site and On-site Integration Skills
- Change Management Skills
- Early Engagement Skills and Knowledge for MMC

Interestingly, Material Science, Material Technology and Sustainability knowledge and/or roles, were not listed or identified at the initial stage of the survey as can be seen above. However, they did arise when respondents were asked for additional skills sets needed.

Although there appears to be many MMC roles and skill categories, it shows the breadth and scope of the various pre-fabrication and modular solutions that are being provided across a diverse range of industry sectors, by Off-site Manufacturers, in Ireland. These roles and skills are very much driven by the production/manufacturing approach that is MMC and the categories definitions. (i.e. the 7 categories in the report from the MHCLG Industry Working MMC Group,2019).

Skills Needs Identified

The chart below presents the key MMC Skills needed according to the MMC Survey

Skills Trends / Results

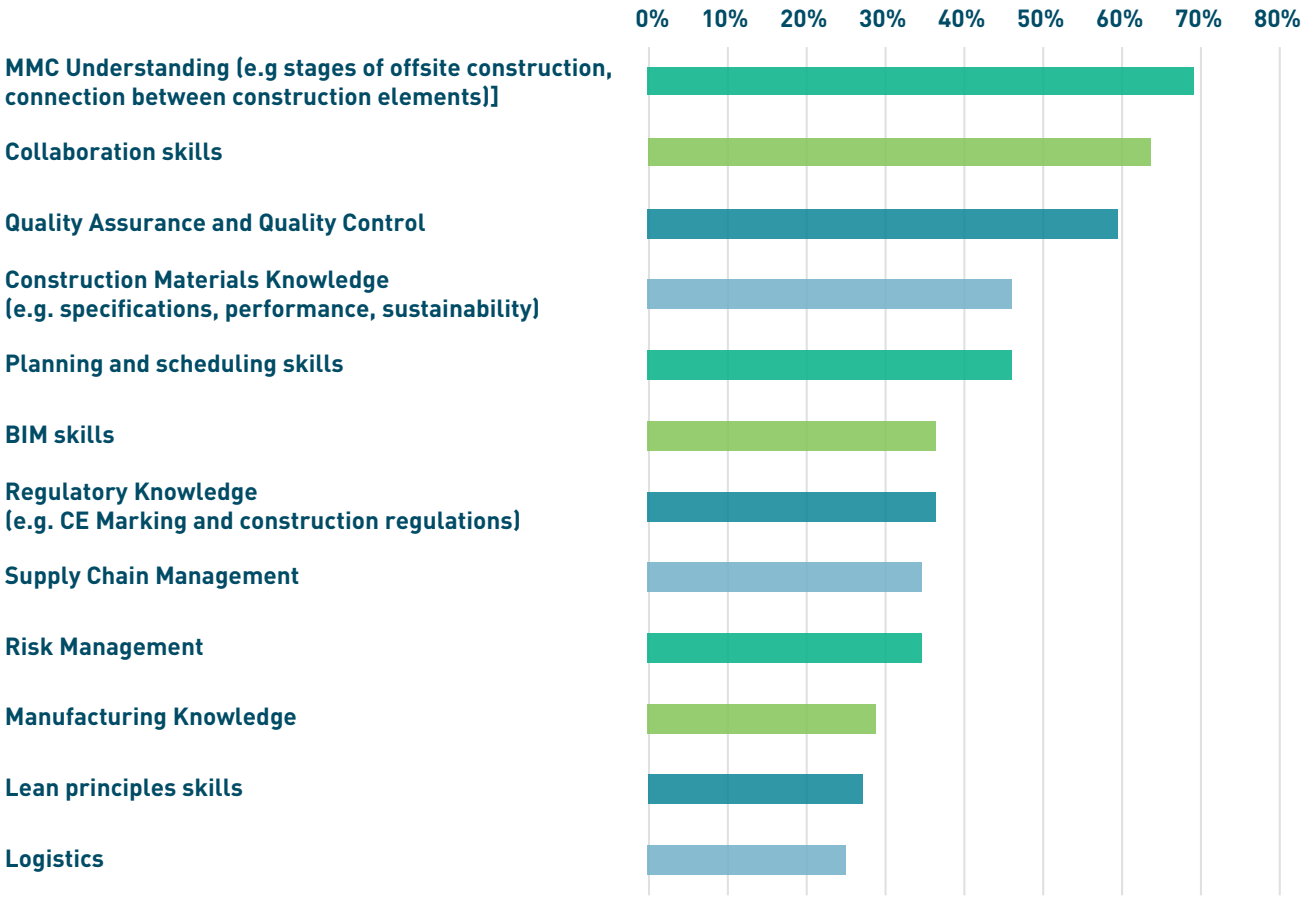


Figure 3.17: MMC Skills trend

MMC skills needs are consistent regardless of construction technique used or type of MMC solution to be applied. MMC adoption will lead to an increased demand for technical, professional and office-based support roles. There will also be the need to up-skill existing workers to cover the site management, integration, on-site placement and assembly that will be increasingly required for MMC. In addition, professional, management, technical and non-manual construction workers will need to acquire digital skills (BIM/Data analytics) as they will increasingly become part of construction work in the future.

The research findings regarding MMC skills are summarised below:

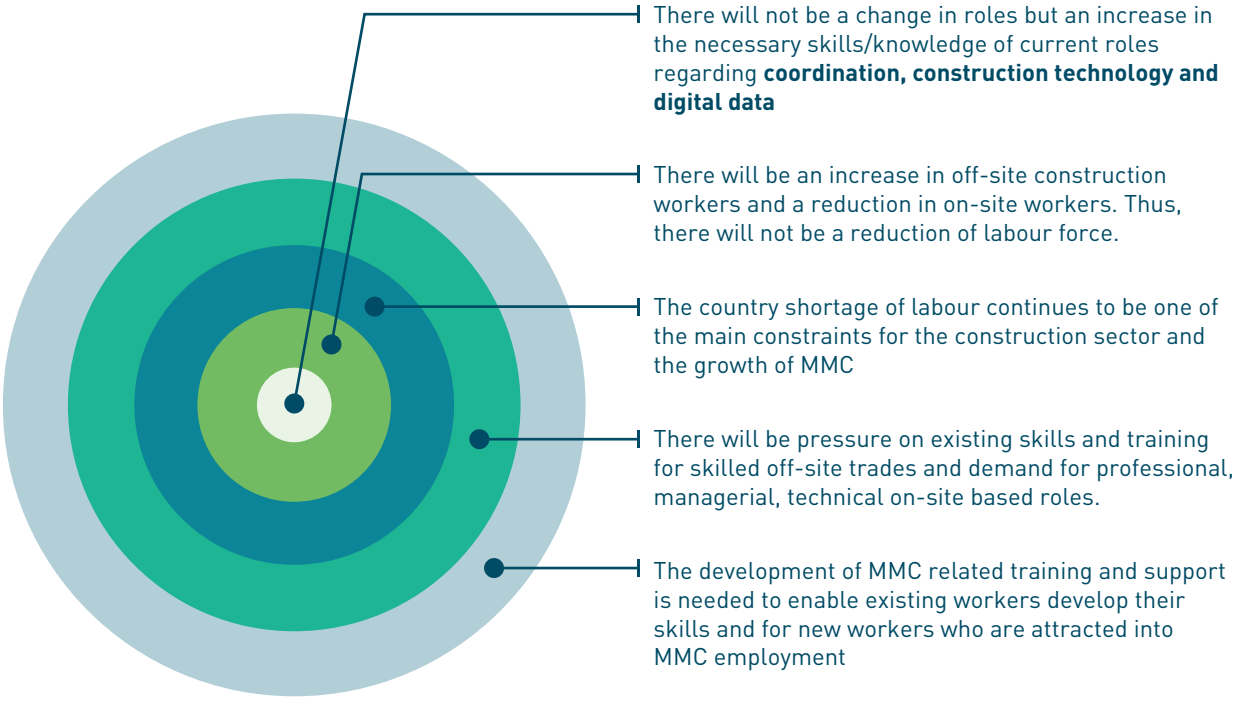


Figure 3.18: MMC Skills Trend (Source – Research database analysis)

When asked what solutions they would propose to meet the skills gap/labour shortages in the construction sector, the responses, although rich and varied, belonged broadly to five categories as listed below:

- Engaging with Transition Year/School Leavers, on the benefits of a career path into Off-site Construction / MMC
- Focus on MMC module(s) in Apprenticeship programmes.
- Creation of short courses/training in MMC
- Ensuring that Modular Construction and MMC are included in relevant 3rd Level courses, particularly in Architecture, Engineering, Construction and Quantity Surveying
- Requirement for a Project Management/Site Supervisors upskilling training course in MMC (perhaps delivered as a CPD course)

It is clear that the respondents cite the above as the key steps to support MMC roles and skills into the near future and to make MMC an attractive and innovative career choice, both for those upskilling in the construction sector or for those wishing to transition into MMC from another sector. This indicates that awareness and training/education in current Pre-fabrication, Modular Construction, Off-site Manufacturing and MMC solutions is needed at all levels, from NFQ Level 4, 5, 6, 7, 8 and up to NFQ Level 9, as either part of current curriculums or as dedicated courses on MMC. Provision offerings will need to be both certified and uncertified in order to meet the needs of the different target audiences. This is further borne out by the responses received during the interviews with the Off-site Manufacturing Providers.

The survey responses, coupled with the MMC experience of respondents, is seen as beneficial as a baseline measure of the current MMC roles and skills required for the OSM sector and the OSM Providers as there has been no research done on this before.

Worth noting from the literature reviews is that some barriers to further adoption for upskilling for MMC roles remain, as cited by Mourão, L. B. (2021) in the below table, with MMC skill gaps highlighted:

MMC Skills Gap Ranking Table – Identified barriers ranked by their mean rating

Barriers	Rank
Current education and training still focused on traditional construction	**4.00**
Lack of understanding of the advantages of OSC	3.73
Changes after production has started are expensive	3.73
Lack of incentive to support this approach by government	3.67
Higher levels of literacy in information communication technologies is required	3.67
There is a lack of Designers and constructor's expertise about OSC	3.62
Manufacturers present capacity	3.53
Higher Off-site Skills required	3.51
Late contractors' involvement	3.49
Resistance from stakeholders to use off-site components/modules	3.47

Figure 3.19: MMC Skills Trend 'as cited by Mourão, L. B. (2021).

This shows that within the top 10 barriers to MMC implementation identified, MMC skill gaps appear five times in various ways. Similar studies in New Zealand show that a lack of understanding or training in MMC was impacting on further adoption and implementation of Off-site Manufacturing/Pre-fabrication solutions for the construction sector. (Shahzad, W. M., June 2011)

Therefore, the key solutions to overcome the skills gap require the improved availability of MMC training and education courses. This is not currently acknowledged or captured within the Action Plan for Apprenticeship 2021 - 2025 Strategy document, 3rd Level Educational University or Institutes of Technology curricula, nor within any ETB or Skillnet Ireland training provider brochures. This is also reflected in all six OSM providers interviews where they state that they have looked and sought such MMC training for their staff and have resorted to in-house customised MMC inductions, coupled with 6-12 months on-the-job training provided for new starts.

Off-site construction offers a valuable solution to several issues facing housing delivery in Ireland – increasing the speed of delivery, delivering more sustainable homes and reducing the need for on-site labour. This contribution can only be achieved, however, if there is engagement from all stakeholders, including the off-site construction sector itself and the government. In addition, the housing sector can learn a lot from the MMC advancements and approaches taken in the life sciences, data centre and semiconductor sectors, all of which have applied innovative MMC solutions. They also have the lessons learnt, for different aspects of implementing MMC for complex projects, that could be shared with other OSM Providers.

MMC Education and Training

In terms of identifying what formal MMC training courses are available, the Architectural, Engineering, Construction Management and Built Environment course offerings of Universities and Institutes of Technology, both at undergraduate and post-graduate level, were reviewed to ascertain what modules or whole MMC programmes were being offered. Similarly, a review was undertaken to verify the accredited professional college courses on the RIAI and SCSI website approved list, to identify if any course offers MMC related modules. Apprenticeships were also reviewed. A summary table of courses reviewed is in Appendix 4.

No university or third level education body providing a course or short module, within Architecture, Engineering or Surveying on MMC was found, though Construction Technology is delivered, but may not encompass the detail that is currently being undertaken by large Irish companies and multinational clients at present, particularly within semiconductor, data centre and biopharmaceutical projects.

There is, however, a **Manufacturing Technician and Engineering Apprenticeship** (www.manufacturingapprenticeships.ie) that was made available in September 2021 and would meet some construction OSM skills needs. While an apprenticeship, there are Level 6 and Level 7 options and the programme would be suitable for a cross section of employees in MMC providers who wish to gain a recognised certification in MMC, whether qualified tradesmen, factory floor workers or employees with degrees, as there is nothing currently available specific to their roles.

There is also the **Advanced Manufacturing Training Centre of Excellence (AMTCE)**, located in the Xerox Technology Park, Dundalk, which has been established by Louth and Meath Education and Training Board (LMETB) to address the training needs of the advanced manufacturing sector in Ireland. Ref: https://amtce.ie/. Again, while not specific to MMC, a number of the courses offered could be relevant to some MMC providers.

Monaghan ETB is currently running an evening course, one night per week for three hours, over a 12-week module on Fault Finding. Off-site Manufacturer (OSM) #6 has recently placed two of their staff members on this course as 'problem-solving' is a key skill set needed to support their Modular Construction growth and capabilities.

Other than those listed above, the only relevant modules found in 3rd Level Institutes are

- Construction Technology and Thermal Insulation
- Cladding and Fabrication Technology
- Building Materials & Environmental Science
- Building Structures
- Framed Structures
- Advanced Building Techniques
- Material Technology
- Materials Science and
- Sustainable Design

These are found in construction and non-construction related courses.

In addition, **Fab-Lab**, based in University of Limerick (UL) have a specific course on Digital Innovation and Research geared towards the manufacturing sector, which has been of interest to Off-site Manufacturer (OSM) #2.

The current provision does not meet the needs of the growing MMC sector and so there is a strong and immediate need to create and develop modules related to the MMC competency requirements identified throughout the training and education infrastructure.

Below is a matrix of the MMC roles and related skills needs identified as part of this research:

Roles / MMC Skills	Awareness & understanding	MMC Definitions	Modular solutions	Pre-assmebly and Assembly techniqiues	Industrial Maufacturing	Factory Production Control	Quality Control knowledge	CE marking knowledge	Lean Manufacturing principles	Lean Six Sigma	Logistics / Transportation	Procurement / Supply-chain management	Planning & Scheduling	Technical Design	Material Technology	Engineering	Data Analytics	Innovative techniques	Digitalisation	Automation	Robotics	Material Science	Sustainable Construction	MMC Whole life-cycle costing
General operative	X	X	X	X			X																	
Metal fabricators	X	X	X	X			X												X					
Machine / CNC technician	X	X	X	X	X	X	X	X											X					
Welders	X	X	X	X	X			X											X					
Plumber	X	X	X	X	X			X											X					
Electrician	X	X	X	X	X			X											X					
Carpenter	X	X	X	X	X			X											X					
Tiler	X	X	X	X	X			X											X					
Painter	X	X	X	X	X			X											X					
Plasterer	X	X	X	X	X			X											X					
Window and Door Fitters	X	X	X	X	X			X											X					
Steel Erectors / onsite Assemblers	X	X	X	X	X			X											X					
Riggers / Logistical operatives	X	X	X	X	X			X			X	X	X						X					
Factory Floor supervisor	X	X	X	X	X	X	X	X	X	X	X	X	X						X					
Production manager	X	X	X	X	X	X	X	X	X	X	X	X	X						X					
Quality Assurance / Quality Control	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X					
Procurement management	X	X	X	X		X	X	X	X		X	X	X		X			X	X					
MMC Buyer	X	X	X	X			X	X	X		X	X	X		X			X	X					
Estimation	X	X	X	X				X					X	X	X	X		X	X					
Designer	X	X	X	X		X		X						X	X	X		X	X			X	X	X
BIM technician	X	X	X	X				X									X	X	X				X	X
Engineer	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X					
Quantity Surveyor	X	X	X	X	X			X	X		X	X	X	X			X	X	X					
Finance manager	X	X		X								X	X				X		X					
Accounts executive	X	X											X				X		X					
Human resources manager	X	X	X									X	X				X		X					
Sustainability manager	X	X	X	X		X		X	X				X		X			X				X	X	X
Business development manager	X	X	X		X			X	X		X	X		X	X	X		X	X				X	

Figure 3.20: Proposed MMC skills matrix by role (Source Quality Positive Limited 2022)

As of yet it is unclear what roles skills related to automation and robotics will impact and what the needs will be. However, there will be competency requirements in these areas in the not-too-distant future.

As can be seen above there is a breadth of needs regarding competency development for the MMC sector. The solutions to these lie in both training and education provision, in both certified and uncertified solutions and in formal, non-formal and informal learning opportunities. The below MMC Education and Training Pathway offers some initial steps which would be useful in meeting the needs of the sector. While the NFQ levels are used as indicators to show the type of knowledge, know-how, skill and competences needed it does not mean to indicate that certification would be necessary.

MMC Training pathway

Proposed MMC Education and Training needs requirements

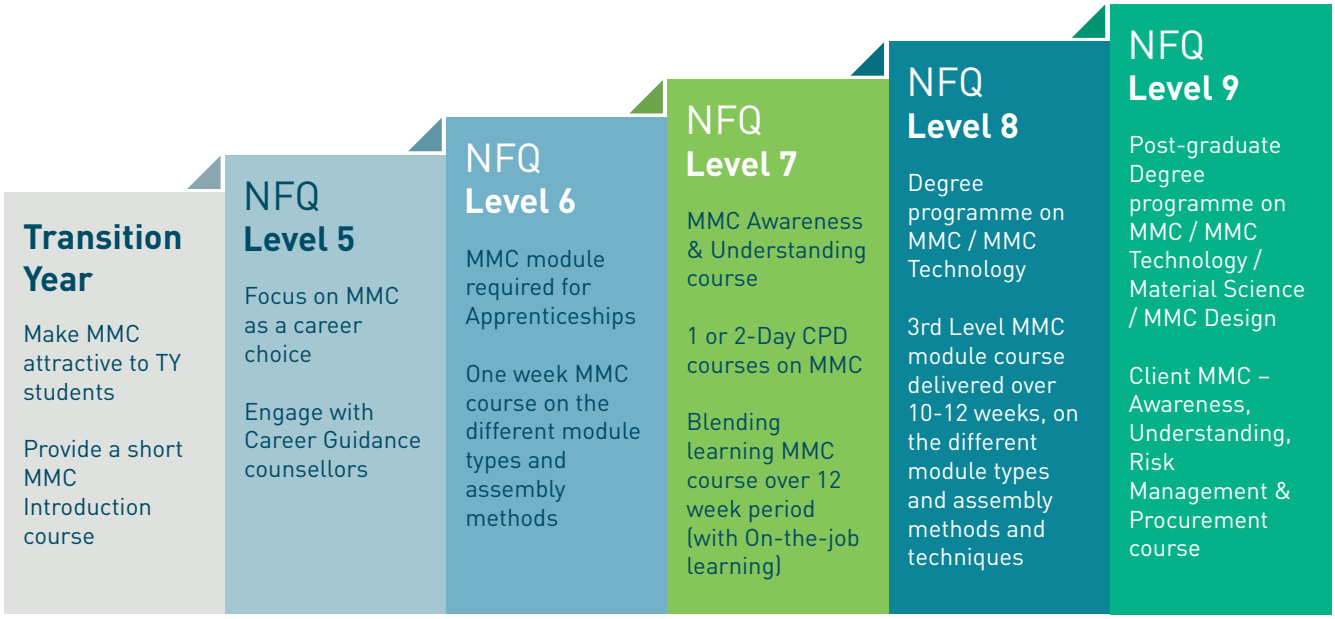


Figure 3.21: Proposed MMC Training pathway (Source Quality Positive Limited 2022)

Stemming out of the desktop research, the OSM provider interviews and the focus group, the below MMC modules or course elements should be considered, as a starting point, for development by training and education providers in conjunction and partnership with Off-site Manufacturing companies, professional bodies and other construction companies who will be the main customers for this training and education provision.

MMC topics for further education and 3rd level institutions

- Procurement & supply-chain management
- Off-site procurement models and procurement routes options
- Collaborative approaches
- Early Contractor Involvement (ECI) – with associated understanding of design freeze
- Identification of sustainable construction requirements
- Whole Life Cycle Costing (WLCC) assessments
- Risk management and risk mitigation methodologies
- Engineering and technical knowledge, particularly for MEP (Mechanical, Electrical and Piping) modules, skids, assemblies
- Production facility assessments and pre-approvals
- Production scheduling and management
- Off-site sequencing and on-site co-ordination – utilising BIM and digital tools
- Off-site fabrication including associated EN 1090 structural welding requirements
- Off-site QA/QC inspections, including Certification requirements i.e. CE marking, Fire, etc
- FATs and SATs i.e. Factory Acceptance Testing and Site Acceptance Testing
- On-site Construction Cranage, Lifting, Rigging and Assembly (to tolerances)
- Pre-commissioning and commissioning activities (on-site)
- Module/System sign-off and certification including building regulations /BCAR 2014 certification, EPD's and DoP certificates

While many of these may seem to be provided for in the current offerings, the business model changes the context and how these elements need to be managed. For example, to leverage the full benefits of MMC, it requires a new approach to risk management and risk sharing models, that current risk management contracts and procurement models do not fully allow, such as traditional procurement, management contracting, design and build type contracts. Therefore, more collaborative and early engagement type approaches are needed, with trust and risk sharing built in from the outset, such as in alliance or collaborative framework agreements, using MMC performance specifications. Additionally, due to the increased tolerance achieved offsite in a manufacturing factory environment, the modular assembly connections points require precision for re-assembly connection onsite. Therefore due to the millimetre tolerances necessary, it is critical that transportation, cranage, lifting, rigging and assembly on-site is carefully managed, ensuring that final point of field connections are accurate. OSM Providers, provide their own on-site assembly teams, that travel with each assembly to either oversee or to manage the final installation in situ onsite, as they may still hold the risk and associated warranties related to these pre-fabricated assemblies / modules, prior to final installation, connection and testing / certification (depending on the contract agreements).

The above needs to also encompass a Total Cost of Ownership (TCO) and an 'end-to-end' circular economy process-based approach, from procurement, design through to fabrication and on-site delivery and assembly. At present this is currently provided through a process of 'osmosis' through the mature clients, design companies and specialist contractors operating in an OSM context.

In addition, MMC would have different modular process skillsets, engineering and technical knowledge requirements across different built environment sectors, such as residential, commercial fit-out, infrastructural, educational, healthcare right up to life sciences, data centres and semiconductor facilities.

The competency needs of those involved in MMC, while related to both construction and to manufacturing cannot be provided by those competent in either. It is the competency in both that creates the unique skillset. The competencies required are a mixture of those found in construction, manufacturing and supply chain management. It is therefore logical that personnel from these diverse departments will need to work together and in collaboration with the MMC Working Group in order to generate the necessary solutions.

Section 4:

Conclusion and Recommendations

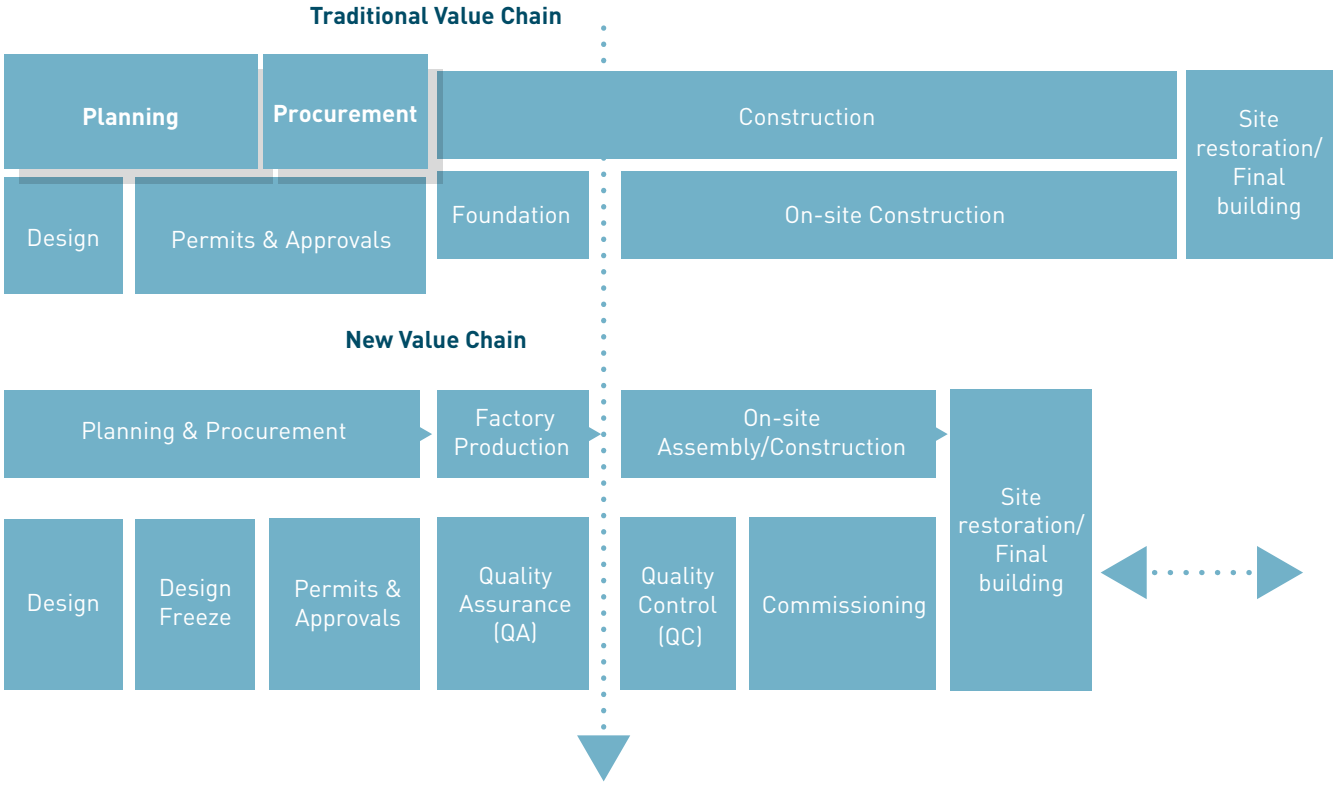
Conclusion and Recommendations

The research set out to:

- Conduct a Value Chain Analysis of the current construction business model
- Reimagine the construction value chain using Modern Methods of Construction (MMC)
- Summarise how MMC are impacting the Irish and international construction sector
- Determine the implications of MMC on the roles and skills required to perform effectively in the sector
- Propose recommendations to construction employers to address the challenges created by using modern methods of construction in relation to careers and skills
- Propose recommendations to education and training providers when addressing the future skill requirements of the construction sector.

The demand for pre-fabrication/modular construction here in Ireland is rapidly increasing and similarly so is the demand for the related current and future skill needs to be met.

Client demand for off-site construction and manufacturing solutions is increasing, with the key drivers being around productivity demands, the current labour and skills shortages, material availability, market dynamics and sustainability requirements for the built environment. This is in addition to the present Covid-19 pandemic situation, coupled with pent-up demand for buildings and the realisation of clients' strategic objectives, to meet their current and medium-term needs. The time-line benefits and related reduction in costs can be clearly seen in the comparison of the two value chains in the diagram below.



Summarise how MMC are impacting the Irish and international construction sector

In many countries, MMC is still very much an outlier. But there are strong signs of what could be a genuine broad-scale disruption in the making. Multiple factors impact whether a given market is likely to embrace modular construction. The real estate demand, the availability and relative costs of skilled construction labour and the housing crisis faced by many countries, has accelerated the demand for MMC solutions from clients (McKinsey 2019). The global SARS-CoV-2 pandemic has also impacted upon global supply-chains and thus has resulted in a shift by companies to more reliable production capacity, which has increased pre-fabricated solutions off-site for the construction sector.

According to the interviewees and the literature review, particularly as cited by McKinsey & Company, in both 2019 and 2020, MMC creates a disruptive business model, which will have profound effects on how construction projects will be delivered and resourced over the coming 10 years. These effects include

- Construction costs and lifetime costs of the building are reduced
- Scheduling of builds that is more efficient
- Building times and costs are more predictable
- Increased sustainability

Some of the rise in popularity of MMC over the last few years in Ireland is due to the potential solution that this construction method can offer to the housing crisis. Moreover, according to the OSM interviewees, the growth in the demand for student accommodation, build to rent and hotels in the country in the last five years is also a key driver. Thus, the requirement by the market for fast-tracked construction projects drives off-site construction as the realisation of the benefits of this approach is occurring in the market and the use of MMC will start to become a requirement.

Impact of MMC on the roles and skills needed

It is clear that there are many advantages to the implementation of MMC. While a number of factors create barriers to its uptake and effective implementation, a lack of properly trained and educated personnel throughout the supply chain is one of the main barriers identified.

The shortage of labour continues to be one of the constraints for the construction sector and results in the increased need for the use of MMC. In order to be able to meet this demand there will be a need to up-skill existing workers to cover site management, integration, on-site placement and assembly that will be increasingly required for MMC. Professional, management, technical, and non-manual construction workers will need to acquire digital skills (BIM/Data analytics) as they will become an increasing part of construction work in the future, both on-site and off-site. There will be pressure on existing skills and training for skilled off-site trade occupations, however demand for professional, managerial and technical on-site based roles will continue. With more use of MMC, there will be potentially more demand for skills related to co-ordination of on-site activity and assembly on-site.

MMC skills requirement is consistent, regardless of the construction technique used or type of MMC solution to be applied. Increased MMC adoption will lead to an increased demand for the related technical, professional and office-based support roles. There is a need for the development of MMC related training and support for existing workers to develop their skills and for new workers

The key future workforce requirements to support MMC have been identified as:

i. MMC Understanding/Construction Materials knowledge – off-site and on-site knowledge are fundamental. The perfect integration of on-site and off-site structures and assemblies are key for effective implementation.

ii. Collaboration skills - High coordination its necessary from design (design freeze) to delivery. Integration for effective logistics will require supply chain management skills and effective risk management.

iii. Quality Assurance and Control - Construction factory production and on-site assembly require high quality and standards

iv. Planning and Scheduling - The planning and time frame production of off-site /on-site modules are key. Logistics is also one of the main elements

v. BIM / Data Analytics / Regulatory Knowledge - The interface among modules and the current regulations compliance are important pieces of MMC.

Recommendations to construction employers to address the challenges created by using modern methods of construction in relation to careers and skills:

The competency needs of those involved in MMC, while related to both construction and to manufacturing cannot be provided by those competent in either. It is the competency in both that creates the unique skillset. While training and education providers can do much to assist in the development of the skillsets through the provision of relevant training and education solutions there are actions that those in the sector can also do. The below are a number of suggestions:

» Create a MMC Working Group mainly to share best practices but also to:

- Promote a culture of innovation, MMC technology understanding and mentoring.
- Create a MMC professional development path and MMC skills matrix.
- Identify the core MMC skill set with details on competencies required
- Work with a facilitator to identify the most appropriate broad solutions for the competencies identified
- Work with training and education providers on the development of appropriate provision at all levels. (See indicative Training Pathway next page)
- Promote MMC to career guidance counsellors throughout the education system and to 3rd level students during career fairs.

Key to ensuring relevant and properly resourced training and education provision is a cohesive industry grouping that has a clarity in what its needs are and that is prepared to assist in the development of the solutions.

Recommendations to educational and further training providers when addressing the future skill requirements of the construction sector

It is clear that MMC is becoming a more important part of the construction sector and that addressing the skills needs is critical to its increased uptake which, in turn, is critical to government targets for Housing for All and Project 2040 being met. It is therefore recommended, in general, that training and education providers in the realm of construction work with those in the sector to generate relevant solutions for the upskilling necessary for the sector.

It is also recommended that it is not just the departments that traditionally provide solutions for the construction sector that are involved. The competencies required are a mixture of those found in construction, manufacturing and supply chain management. It is therefore logical that personnel from these diverse departments will need to work together and in collaboration with the MMC Working Group in order to generate the necessary solutions.

It is also important that provision is offered at all levels, though not necessarily certified, to meet the needs of learners in different roles and at different levels in terms of education and in terms of position in MMC companies. The below pathway is a suggestion of how this may look.

MMC Training pathway

Proposed MMC Education and Training needs requirements

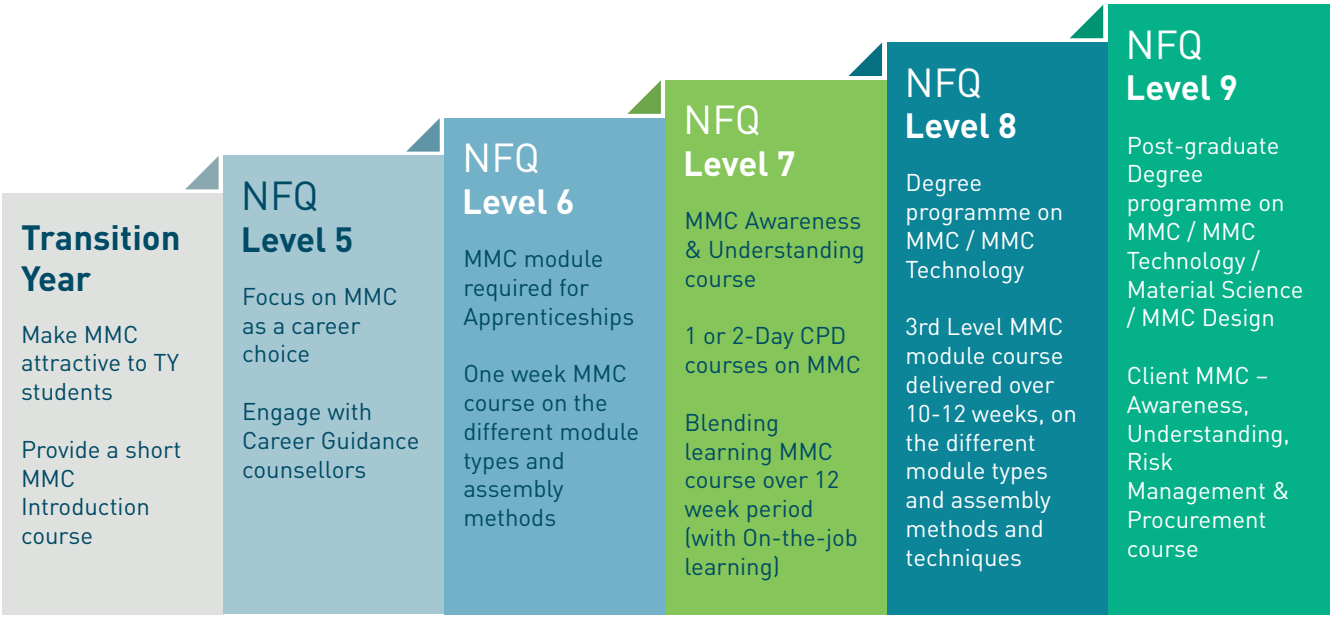


Figure: Proposed MMC Training pathway (Source Quality Positive Limited 2022)

These solutions offered may include, but may not be limited to:

- Create a broader MMC manufacturing technician apprenticeship/trade courses focused on MMC / Modular Construction
- Create CPD and blended learning courses for MMC, both to raise awareness and understanding and to impart current knowledge
- Review curriculum of current technical courses and apprenticeships expanding modules to include MMC related topics
- Create modules with a focus on innovation, modern materials and manufacturing as part of the curriculum for all third level Civil, Mechanical & Electrical Engineering and Construction Studies courses
- Work with the MMC Working Group to develop a factory-based apprenticeship
- Work with the MMC Working Group to develop a broader MMC manufacturing technician apprenticeship
- Directly support the establishment of appropriate training course development & industry alignment with professional bodies
- Develop CPD for architects and engineers in making the design of buildings MMC friendly

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Appendices

Appendix 1

MMC survey questions

1. In your opinion does Ireland currently have the working skills to successfully apply MMC?
2. What are the necessary MMC roles and skills requirements to perform in the sector?
   (1=Strongly Disagree, 2=Disagree, 3=Neutral, 4= Agree, 5=Strongly Agree)
3. Are there any other skills/roles that you believe are or should be performed?
   If Yes, please mention in the space "Other".
4. What solutions would you propose for the skills gap/labour shortages in the construction sector?
5. Number of years of professional experience with Modular Construction / Off-site Fabrication.
6. Please identify the construction business sectors that you are involved in with Modular Construction/Off-site fabrication. (Tick as applicable)
7. Your company's size.
8. What is the Annual Turnover of your organisation? (€ millions)
9. Name of your Organisation / Company *(optional))*
10. Email address *(optional)*

Appendix 2

OSM Provider Interview Questions

1. A Value Chain in construction is a type of business model that includes all the different activities that are needed for the project. Within the construction industry, a Value Chain (steps) is created to ensure that a project is successful from the planning stage, all the way to the completed and approved building structure. Could you describe or propose the best Modular Construction Value Chain that delivers value for Off-site Construction and the Skillset that are needed?
2. In your opinion what are the differences between the current Construction Value Chain (steps) and Modular Construction (MMC) Value Chain? Are there different or additional steps?
3. In your opinion how is MMC impacting the International Construction sector?
4. In your opinion how is MMC impacting the Irish Construction sector?
5. In your opinion what are the necessary MMC roles and skills requirements to perform in the sector?
6. In your opinion does Ireland currently have the working skills to successfully apply MMC? If no, what are your proposed solutions?
7. Could you provide recommendations to construction employers to address the challenges created by using Modern Methods of Construction / Off-site Manufacturing (OSM) in relation to careers and skills?
8. Could you provide recommendations to education and training rroviders when addressing the future skill requirements of the Irish Construction sector?
9. Could you give us an overview of your current MMC / OSM roles?
10. What are the future trends you envisage will arise from increased adoption of MMC / OSM?

Appendix 3

List of MMC Working Group Members

Name	Company	Title / Role	Sectors involved in	MMC Years of experience
Rory O'Connor	Actavo Building Solutions	Design Manager	Residential Commercial Education Healthcare	+15 years
John Whyte	BRE Group (Ireland)	General Manager	**All Sectors**	+8 years Has support from BRE Global UK – a dedicated UK MMC business unit.
Gary Plunkett	Carroll Estates	Construction Manager	Residential Commercial Healthcare	6 years
Eoin Waldron	Castle Modular	Operations Manager	Residential Commercial Healthcare	15 years
James Clifford	Cogent Associates	Associate Director	Residential Student Accommodation Commercial Education Healthcare Industrial Life Sciences	+5 years
Frank Murphy	Cygnum	Operations Manager	Residential Education	25 years
William Power	C+W O'Brien Architects	Director	Residential Commercial Student Accommodation	+15 years

Pat Kirwan Associate	C+W Architects		Residential Commercial Education Healthcare Student Accommodation	+15 years (previously with HJ Lyons Architects)
Susan McGarry	Ecocem Ireland	Managing Director	Residential Commercial Industrial	+10 years
Declan Wallace	Evolusion Innovation	Technical Director	Residential Commercial Education Healthcare	+20 years (Evolusion now bought over by Etex Limited) Off-site construction technology experts.
Lee Murphy	G-Frame Structures Ltd	Director	Residential Commercial Education	+8 years
Martin Lydon	LMC Group	Managing Director	Residential Commercial Education Healthcare	+15 years
Stephen Ashe	Linesight	Director	Residential Commercial Education Healthcare Industrial Life Sciences	+10 years
Claire Lane	LMC Group	BIM Manager / Associate Director	Residential Commercial Education Healthcare	10 years
Peter Browne	Mac Group	Business Development Manager	Residential Commercial	20 years (previously with McAvoy Group)

Micheál Keohane	Modern Homes Ireland	Director	Residential Commercial Education Healthcare	15 years
Derbhile McDonagh	O'Mahony Pike Architects	Director	Residential Commercial Education Healthcare Infrastructure	+10 years
David Browne	RKD Architects	Director	Residential Commercial Education Healthcare	+10 years
Joe Kennedy	Smith & Kennedy Architects	Managing Director	Residential Commercial Education Healthcare	+10 years
Sean Sheridan	Tritech Engineering	Electrical Project Manager	Residential Commercial Education Healthcare Industrial Life Sciences Data Centres	5 years

Appendix 4

List of 3rd Level University / College MMC course summary table (as of 31st December 2021)

University/ College	NFQ Level	Discipline/ Course	MMC Module / elements (Y/N)	Course title
Institute of Technology Carlow	7	Architecture	N	BSc in Architectural Technology
Cork Institute of Technology	7	Architecture	N	BSc in Architectural Technology
Galway Mayo Institute of Technology	7	Architecture	N	BSc in Architectural Technology
Letterkenny Institute of Technology	7	Architecture	N	BSc in Architectural Technology
TU Dublin	7	Architecture	N	BSc in Architectural Technology
Waterford Institute of Technology	7	Architecture	N	BSc in Architectural Technology
Institute of Technology Carlow	8	Architecture	N	BSc (Hons) in Architectural Technology
Cork Institute of Technology	8	Architecture	N	BSc in Architectural Technology
Galway Mayo Institute of Technology	8	Architecture	N	BSc (Hons) in Architectural Technology
UCD	8	Architecture	N	Master of Architecture (MArch) Architecture, Urbanism and Climate Action (MSc) Professional Diploma (Architecture) Planning, Development & Urban Design (MSc) Masters in Urban Design and Planning (MSc)
UCC / Cork Institute of Technology	8	Architecture	N	BSc (Hons) in Architecture
Institute of Technology Sligo	8	Architecture	N	Bachelor of Architecture (Hons) in Architecture (BArch)

Waterford Institute of Technology	8	Architecture	N	Bachelor of Architecture (Hons)
UL	8	Architecture	N	Bachelor of Architecture
TU Dublin	8	Architecture	N	BSc (Hons) Architectural Technology Bachelor of Architecture (Hons) BSc (Hons) Sustainable Timber Technology Professional Diploma in Architectural Practice (PDAP)
TU Dublin	9	Architecture	N	Master of Architecture Master of Architecture (Advanced Entry) Postgraduate Certificate in Building Performance (Energy Efficiency in Design) Postgraduate Diploma in Building Performance (Energy Efficiency in Design) MSc in Building Performance (Energy Efficiency in Design)
UL	9	Architecture	N	M.Arch in Architecture
UCC / Cork Institute of Technology	9	Architecture	N	M.Arch in Architecture
UCD	9	Architecture	N	Master of Architecture (MArch (Hons)

TU Dublin	7	Engineering	N	Automation Engineering Building Engineering Civil Engineering Electrical & Control Engineering Electrical Services Engineering Electrical Services Engineering Technician Engineering (General Entry) Engineering Reliability Management Mechanical Engineering Mechatronic Engineering Process Instrumentation & Automation Structural Engineering Sustainable Energy & Environmental Engineering Sustainable Energy Engineering
UCC	7	Engineering	N	Diploma in Electrical and Electronic Engineering Studies
TU Dublin	8	Engineering	N	Automation Engineering (Hons) Building Engineering Civil Engineering Electrical Services & Energy Management Electrical Services Engineering Engineering (General Entry) Manufacturing Design Engineering Mechanical Engineering Mechatronic Engineering Sustainable Energy & Environmental Engineering Sustainable Energy Engineering
UCD	8	Engineering	N	BSc Mechanical Engineering (Engineering Science)
Trinity College Dublin	8	Engineering	N	Engineering (General) Engineering with Management Environmental Science and Engineering

NUI Maynooth	8	Engineering	N	BSc. Electronic Engineering BSc Robotics and Intelligent Devices
NUI Galway	8	Engineering	N	Civil Engineering Electrical and Electronic Engineering Electronic and Computer Engineering Energy Systems Engineering Engineering (Undenominated) Mechanical Engineering
UCC	8	Engineering	N	BE (Hons) (Civil, Structural and Environmental) BE (Hons) (Electrical and Electronic) BE (Hons) (Energy) BE (Hons) (Process and Chemical)
UL	8	Engineering	N	BSc. in Technology Management BSc. in Aeronautical Engineering BSc. in Construction Management and Engineering BE/MEng in Civil Engineering BSc. of Engineering in Design and Manufacture BE/MEng of Engineering in Mechanical Engineering BSc. of Science in Immersive Software Engineering
NUI Galway	9	Engineering	N	Civil Engineering (ME) Electrical & Electronic Engineering (ME) Electronic & Computer Engineering (ME) Energy Systems Engineering (ME) Enterprise Systems (MApplSc, full-time [FT] or part-time [PT]) Mechanical Engineering (ME) Mechanical Engineering (MSc) TechInnovation (Distance Education) (MSc)

TU Dublin	9	Engineering	N	MSc in Energy Management ME in Mechanical Engineering Sustainable Development Sustainable Electrical Energy Systems Sustainable Infrastructure
UCC	9	Engineering	N	ME (Civil, Structural and Environmental) ME (Electrical and Electronic) ME (Energy) ME (Process and Chemical)
UCD	9	Engineering	N	ME in Mechanical Engineering ME in Energy Systems ME in Materials Science & Engineering MEngSc in Engineering Management MEngSc in Materials Science & Engineering
Trinity College Dublin	9	Engineering	N	MSc in Engineering (Environmental / Structural and Geotechnical / Transport / Sustainable Energy) MSc in Bioengineering MSc in Electronic Information Engineering MSc in Mechanical Engineering
TU Dublin	7	Construction	N	Bachelor of Technology (Ord) Construction Site Management Bachelor (Ord) in Construction Site Management
TU Dublin	8	Construction	N	BSc. (Hons.) in Construction Management
NUI Galway	8	Construction	N	Project and Construction Management
TU Dublin Blanchardstown	8	Construction	N	Design, Technology and Innovation
TU Dublin	9	Construction	N	Post Grad Diploma in Project Management

Trinity College Dublin	9	Construction	N	Applied Building Repair and Conservation Construction Law and Contract Administration Environmental Monitoring, Assessment and Engineering Fire Safety Practice Health & Safety in Construction Project Management Sustainable Energy
TU Dublin	8	Quantity Surveying	N	BSc. (Hons.) in Quantity Surveying and Construction Economics
NUI Maynooth	8	Quantity Surveying	N	MSc. Geographical Information Systems & Remote Sensing
IT Sligo	8	Quantity Surveying	N	BSc. (Hons.) in Quantity Surveying (Online) BSc. (Hons.) in Quantity Surveying BSc. (Hons.) in Construction Project Management (add-on) BSc. (Hons.) in Construction Project Management & Applied Technology
Technological University of the Shannon *(formerly AIT)*	8	Quantity Surveying	N	BSc. (Hons.) in Quantity Surveying
Carlow IT	8	Quantity Surveying	N	BSc. (Hons.) in Quantity Surveying
Dundalk IT	8	Quantity Surveying	N	BSc. (Hons.) in Building Surveying
GMIT	8	Quantity Surveying	N	BSc. (Hons.) in Construction & Quantity Surveying
Letterkenny IT	8	Quantity Surveying	N	BSc. (Hons.) in Quantity Surveying
Waterford Institute of Technology	8	Quantity Surveying	N	BSc. (Hons.) in Quantity Surveying

Technological University of the Shannon *(formerly LIT)*	8	Quantity Surveying	N	BSc. (Hons.) in Quantity Surveying BSc. (Hons.) in Property Valuation & Management
TU Dublin	9	Quantity Surveying	N	BSc. (Hons.) in Quantity Surveying & Construction Economics (full-time) BSc. (Hons.) in Quantity Surveying & Construction Economics (part-time) MSc. in Quantity Surveying (part-time) BSc. (Hons.) in Property Economics (full-time) BSc. (Hons.) in Property Economics (part-time) MSc. in Real Estate MSc. in Spatial Planning MSc. in Spatial Information Management
Technological University of the Shannon *(formerly LIT)*	9	Quantity Surveying	N	MSc. in Quantity Surveying
IT Sligo	9	Quantity Surveying	N	Postgraduate Certificate in M&E Quantity Surveying Higher Cert Property Services & Facility Management
Waterford Institute of Technology	8	Quantity Surveying	N	MSc. in Construction Project Management (full-time) MSc. in Construction Project Management (part-time)

Table - 3rd Level Universities and Institutes of Technology (Source – MMC Skills Needs Research analysis conducted online for various Technology courses on offer, at present, as of January 2022, Quality Positive Limited).

SOLAS have the following Apprenticeship courses listed under the following Manufacturing, Engineering & Construction related disciplines:

» Engineering

- Engineering Services Management L7
- Equipment Systems Engineer L9
- Farriery L6
- Industrial Insulation L6
- Manufacturing Engineering L7
- Manufacturing Technology L6
- Mechanical Automation and Maintenance Fitting L6
- Metal Fabrication L6
- OEM Engineer L6
- Pipefitting L6
- Polymer Processing Technology L7
- Principal Engineer L10
- Sheet Metalworking L6
- Toolmaking L6

» Electrical

- Aircraft Mechanics L6
- Electrical L6
- Electrical Instrumentation L6
- Electronic Security Systems L6
- Industrial Electrical Engineer L7
- Instrumentation L6
- Refrigeration and Air Conditioning L6

» Construction

- Brick & Stonelaying L6
- Carpentry & Joinery L6
- Geo-Driller L6
- Painting & Decorating L6
- Plastering L6
- Plumbing L6
- Scaffolding L5
- Stonecutting & Stonemasonry L6
- Wood Manufacturing & Finishing L6

» Logistics

- Lean Sigma Manager L9
- Logistics Associate L6
- Supply Chain Associate L7
- Supply Chain Manager L9
- Supply Chain Specialist L8

Appendix 5

Acronyms used

Acronym	Full Description
BC(A)R	Building Control (Amendment) Regulations 2014
BIM	Building Information Modelling
CITB	Construction Industry Training Board (UK)
CNC	Computerised Numerical Control
DETE	Department of Enterprise, Trade and Employment
DES	Department of Education and Skills
DoC	Declaration of Conformity certificate
DoP	Declaration of Performance certificate
DfMA	Design for Manufacture and Assembly
ECI	Early Contractor Involvement
EPD	Environmental Product Declaration
ETB	Educational Training Board Ireland
ETB	Educational Training Board
FAT	Factory Acceptance Testing
FETAC	Further Education and Training Awards Council (Ireland)
HETAC	Higher Education and Training Awards Council
HfA	Housing for All strategy 2021-2030
IOT	Institutes of Technology
JIT	Just in Time
MEP	Mechanical, Electrical and Piping
MHCHG	Ministry for Housing, Communities and Local Government (UK)
MMC	Modern Methods of Construction
OSM	Off-site Manufacturing
NFQ	National Framework of Qualifications (Ireland)

QA	Quality Assurance
QC	Quality Control
QQI	Quality and Qualifications Ireland
SAT	Site Acceptance Testing
SOLAS	An tSeirbhís Oideachais Leanúnaigh Agus Scileanna The State agency tasked with building a world class Further Education and Training (FET) sector
Skillnet Ireland	Ireland's business support agency focussed on enterprise-led talent development
VSM	Value Stream Map
VCA	Value Chain Analysis
WLCC	Whole Life Cycle costing

About the Authors

Martin Searson

Martin Searson is the CEO of Quality Positive Limited, specialising in providing support services and technical advice to the engineering and construction sectors. Services include operational excellence, sustainable construction, modularisation and process automation. Martin has 20+ years mechanical and electrical (M&E) industry experience. Previously, he was the Group M&E Quality & Lean Manager for a large construction company. He has extensive quality management experience following work on key projects across a range of sectors including Semiconductor, Data Centres, Biopharmaceuticals, Windfarms, Substations up to 400kV, Industrial Manufacturing, Commercial fit-outs and Residential projects, across Ireland, UK and Mainland Europe. Martin was a winner of six **National Quality Awards** (with 7 consecutive nominations) and a **Lean Business Ireland Award** in 2019, for his approach and implementation of quality management and lean construction principles in a company, operating in Ireland, UK & Europe. Martin currently holds a Masters in Quantity Surveying and an Honours Degree in Applied Science from Trinity College Dublin.

Viviane Leuchtenberg P. Esposito

Viviane Leuchtenberg P. Esposito is Quality and Operations Manager with Quality Positive Limited with the aim of driving productivity improvements, lean solutions and business strategies in the Irish engineering and construction sector. She is currently involved in Quality Management delivery, ISO certifications, building surveying advice, inspections, audits, and BCAR (2014) regulations. Viviane is a civil engineer with an extensive military and multinational corporation background. She has managed engineering projects including roads, bridges, ports, integrated mining industry chains and multinational factories, providing contract management, lean continuous improvement solutions, strategic sourcing procurement and operational excellence. Viviane is a Lean Six Sigma Green Belt professional and has completed a Masters in Quantity Surveying at Limerick Institute of Technology, an MBA, a Post Graduate degree in Construction Management and a Post Graduate degree in Project Management. She has also conducted research and development on modular construction and modern methods of construction (MMC), looking constantly for ways to improve engineering and construction.

Construction Professionals Skillnet

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An Roinn Breisoideachais agus Ardoideachais, Taighde, Nuálaíochta agus Eolaíochta
Department of Further and Higher Education, Research, Innovation and Science