

BARRIERS TO THE IMPLEMENTATION OF MODULAR CONSTRUCTION IN IRELAND: A CASE STUDY FROM AN IRISH SMALL AND MEDIUM-SIZED ENTERPRISE PERSPECTIVE

Shane Carmody¹, John P Spillane and Noel Clarke

Irish Construction Management Research Centre (ICMRC), School of Engineering, University of Limerick, Limerick, V94 T9PX, Ireland

Traditional construction has begun to struggle with societal demands. Modular construction and pre-fabrication have been studied, providing clear insight into their capabilities. An absence of research based on modular construction in Ireland is evident. The aim of this study is to identify the factors that are inhibiting modular construction adoption in Ireland. A qualitative research method is applied, using 6 semi-structured interviews with the target case study. The firm is based in the southwest of Ireland, with an annual turnover of €10 million, with 55 staff employed. Findings from this pilot study show that the barriers are varied yet subjective to the firm. It is evident that education and knowledge is a core solution to overcoming these barriers. It is recommended that modular workshops should be implemented for academia and industry to fully comprehend what volumetric modular is and its capabilities.

Keywords: constraints; innovation; off-site production; prefabrication

INTRODUCTION

Modular construction is a technique that can transfer the construction process into an off-site setting allowing work to concur in a parallel form. The benefits of modular construction are widely researched and reported, highlighting significant gains in projects such as increased productivity, reduced life cycle cost and accelerated construction pace (Wuni and Shen 2020). Furthermore, empirical studies have established that modular construction is more environmentally friendly when compared to traditional construction techniques (Mao *et al.*, 2013). These benefits are recognised across the construction community, with modular construction projects being incorporated across the world in areas such as Spain, Australia, Hong Kong, and the United Kingdom (UK).

Modular construction can be categorised in many different techniques such as prefabrication, preassembly, off-site production, volumetric modular and other ranges of off-site and onsite construction methods (Rahman 2014). For the purpose of this investigation, volumetric modular will be the construction method examined.

¹ shane.carmody@ul.ie

Primarily looking at the barriers preventing it from being integrated in Ireland's construction industry, specifically within Small and Medium sized Enterprises (SME's). The purpose of solely investigating volumetric modular is due to the fact that this is a relatively new concept within the Irish industry. The study also focuses on SME's due to them making up majority of the construction firms in Ireland (92.4%) (Central Statistics Office 2014). A small enterprise is defined as a company that does not exceed €10 million annual turnover and has less than 50 employees. Similarly, a medium sized enterprise is defined as a company that does not exceed €50 million and has 50 to 249 employees (Enterprise Ireland, 2022).

In volumetric construction projects, modules are fully fitted with walls, ceilings, floors and all furniture, fittings, and equipment (Hwang *et al.*, 2018). In addition, these modules are transported from the manufacturer to the project site for installation. This type of construction thrives on projects with design features that are repetitive such as prisons, hotels, schools, and hospitals (Hwang *et al.*, 2018). Despite this, countries such as Japan have adapted to the constraint of its design. Linner and Bock (2012), identify that Japan has one of the strongest construction industries globally, producing approximately 150,000 housing units per annum that are constructed in an off-site setting. Furthermore, their research identifies that approximately 15% of Germany's housing output is prefabricated while Austria's prefabricated housing output is 33% (Linner and Bock 2012).

Academic research on Ireland's modular construction sector is limited. The traditional construction technique still thrives in Ireland despite the often-inadequate results that it produces. PricewaterhouseCoopers (2019), report on the National Children's hospital, highlights that the project expenditure has increased by 450 million euro. Additionally, the project timeline has increased by a minimum of 16 months. This example provides a very brief insight into the traditional construction methods that take place in Ireland. Subsequently, the purpose of this study is to explore the constraints that prevent contemporary construction techniques such as modular construction from being used in Ireland within SME's.

It is critical to question why these methods are not being adopted despite the success of modular construction in neighbouring countries like the UK. Taylor (2020) has demonstrated that the UK's modular sector is growing at a slow but steady rate. In 2010, the value of the sector was 6.5 billion pounds (Taylor 2010); however, the sector in 2020 was approximately 6.78 billion pounds (Taylor 2020). A significant element in the adoption of modular construction in the UK was a government backed mandate on the use of modern methods of construction. In this mandate, the UK Government is providing financial support of £2.5 billion to support builders who use modern methods of construction (Ministry of Housing, Communities and Local Government, 2019). The improvements that have developed in the UK and Europe unfortunately, have not taken place in Ireland. Previous studies have looked at the barriers towards modular construction in countries such as the UK, United States, China, and Europe, however, studies based on SME's particularly in Ireland are lacking. Thus, this pilot study, which is at the beginning of a wider research project, aims to identify the factors that restrict modular construction adoption within SME's in the Irish construction industry.

Barriers Towards Modular Construction

Barriers that prevent modular construction from being adopted in the construction industry is an area that has received a considerable amount of research. However,

research into this area within the geographical location of Ireland is scant. Nonetheless, regions such as the UK, China, Japan, and the USA have experienced significant research despite very little research being conducted specifically on SME's. Upon completing an extensive literature review, six key themes are identified that are seen as major barriers to the adoption of modular construction. These barriers are identified as; Financial, Design, Knowledge and Skill, Transport and Storage, and Technology.

Financial

When analysing the barriers, costing appears to be an issue that emerges frequently. Rahman (2014) explains from a manufacturing point of view, how the cost of initial set up is extremely high. Furthermore, he states how the construction cost per unit can become expensive if the demand for modular components is low. A fluctuating market is not a fitting environment for start-up manufacturing. Wuni and Shen (2020) state that the early upfront financial commitment compromises the SMEs ability to compete in the industry despite these firms dominating the construction industry. Furthermore, Wuni and Shen (2020) consolidate the issue of the hard-to-achieve economies of scale based on the high initial capital investment. Modular construction can appear to be more expensive initially; however, Zhai *et al.* (2013) states that decision criteria used by firms is primarily cost based rather than value based. Furthermore, the study identifies houses built by modular practices tend to be observed as low-income options which effects the marketability of modular construction (Zhai *et al.*, 2013).

Design

Design flexibility within the traditional construction methods is attractive for architects and clients alike. Modular construction has been associated with the attributes of monotonous design, limited flexibility, and complex maintenance (Zhai *et al.*, 2013). Hwang *et al.* (2018) conducted a case study on a modular project in Singapore. In the research, it states that the project only allowed for limited opportunities to change design. Furthermore, design and planning had to be finalised before any work commenced leading to a lot of additional work (Hwang *et al.*, 2018). Polat (2008) identifies from his study that 62% of designers agree that prefabricated elements somewhat restrict their architectural creativity. These remarks are contradictory as modular construction is excellent from a design perspective for projects such as prisons, hotels, schools, and hospitals where the design is repetitive. Despite this, Rahman (2014) consolidates the views that modular construction is exposed to an inflexibility for late design changes and an early design freeze amongst stakeholders. Albeit these are noted as barriers within the research, opportunities may be available to the construction community to use these scenarios to their advantage.

Knowledge and Skill

The lack of in-house and industry experience surrounding modular construction is an issue that has been widely reported. Jaillon and Poon (2010) conclude that these are major limitations to the modular construction process from an architect's perspective. Furthermore, Rahman (2014) illustrates that the lack of adoption of modular techniques is due to the lack of experience and skills surrounding them. Many construction workers in the industry have little or no experience working with modular construction techniques. Potential clients incorporating modular construction may have to front load a project while also investing in training for operatives. This financial burden has the capability to change a client's route to a more conventional construction technique.

Azhar *et al.* (2013) present in their findings a critical constraint which is "owners' wrong conception". This barrier links with design and cost as clients who do not fully understand how modular techniques perform will delay design and generate a larger outlay. Moreover, the sustainable development of the modular sector may suffer due to the current workforce being transferred from traditional techniques to modular practices (Cheng and Ma 2020). This concern delves deeper by explaining that these professionals will not have the capacity to enhance the modular sector due to them not being taught the practices at a more fundamental level, which displays the need for education systems to upgrade their curriculum.

Transport and Storage

The transportation and storage of large construction elements can be an expensive undertaking. Studies identify that transportation and storage of modular elements to be a huge concern and barrier towards its adoption. Jaillon and Poon (2010) establish that precast element storage accounts for approximately 22% of a sites floor area. This is a significant amount of storage space needed on site, particularly if building within cities or congested areas. Additionally, Hwang *et al.* (2018) identifies the requirement of approval from transport authorities in Singapore to transport their modules. The approval is required 3 days before the intended day of travel. This requirement combined with congested urban areas leaves stakeholders with additional costs and additional burden. Just-in-time delivery is suggested as a solution to this dilemma; however, relying on local authorities to provide passage can be unpredictable. Polat (2008) states that the cost of transportation is directly proportional to the number of truckloads used for delivery and the cost per unit for delivery. Furthermore, Polat (2008) confirms the constraint of transport authorities' regulations with regards to allowable weights capacities, load sizes and tunnel and bridge restrictions. These are indirect factors which may not be initially investigated when choosing construction technique and could potentially lead to higher unforeseen costs footed by the client.

Technology

Technological issues are systems that are not in place or have been altered from the traditional process to serve the modular construction technique. Blismas and Wakefield (2009) indicate in their study that the low levels of information technology integration in Australia has hindered off-site adoption in the industry and has made it uneconomical to use off-site construction processes. Interfacing between components is a constraint which has been highlighted in numerous studies. Wuni and Shen (2020) describe that modular construction requires complex interfacing between modules. The study also explains that technological barriers are generally seen in developing countries, while countries such as the UK, China and Australia rarely encounter these technological issues. Rahman (2014) identifies that if modular practices are combined with traditional techniques, then interface issues are inevitable. This is due to the high tolerance procedures used in factories compared to in-situ practices on-site, causing interface issues when attempting to integrate both components on-site. Additionally, Cheng and Ma (2020) state in their research how an information integration system is vital within prefabrication projects. This can be achieved by incorporating systems such as Building Information Modelling (BIM) within the project. Taking this into account, the issue of BIM adoption and level of maturity within Ireland is cause for concern.

METHOD

This pilot study is at the beginning of initial research, to evaluate the validity of the research topic for further examination, which aims to contribute to both academia and industry. This research paper as part of a wider research project has received ethical approval from the research ethics committee in the University of Limerick. To analyse the barriers that prohibit modular construction from being adopted by SMEs in Ireland, a qualitative research method is selected. The research method is founded initially on an informative literature review. This is followed by a case study which encompasses six semi-structured interviews with industry professionals. The case study has been in operation for over 40 years in the rental prefabrication sector. The firm is now servicing the volumetric sector for over 12 months. A semi-structured interview process is adopted due to the flexibility that it provides to the participants, as it allows a focused investigation of previously identified factors yet allowing participants to identify issues that are not yet disclosed in the literature (Brooks *et al.*, 2016).

Furthermore, this method allows questions to lead from one to the next, providing the interviewer with as much information as possible. The interviews are conducted face-to-face. An open-ended format is used which generated in-depth discourse about prominent issues that faced the SME industry when trying to adopt modular construction. Questions are developed from the literature, taking themes from studies completed in different countries. However, the participants lead the discussion into areas and topics that they felt are of significance. Participants are selected based on criterion selection; minimum of 1 year of current experience working within the Irish modular construction sector, minimum of 10 years' experience within the construction or manufacturing industry, and status of the company they are currently working for (SME).

The interviewees provide their opinion on the barriers that prevent modular construction from being implemented within SMEs in the Irish construction industry. The identities of the participants involved will remain anonymous and confidential information is not revealed. To ensure non-bias, each interview follows the same process, ensuring that instructions provided is identical, provided in the same order and with equal meaning, providing comparable data. The interviewees are all male, who have worked a minimum of 1 year within a modular sector, with minimum of 10 years' experience in construction or manufacturing. Each interview is transcribed once completed. Data is extracted by analysing each response and subsequently identifying any themes provided by the interviewees. The themes are coded, and any key terms and similarities are organised and listed below.

FINDINGS

The interviews commenced with gaining general background information on each participant followed by a discussion on the modular sector in Ireland, its constraints, and the issues they face as a company. All the resultant data from each interview is amalgamated and thematically analysed. Keywords, themes, and topics are identified for discussion. A summary of all the key issues is illustrated in Table 1. The results illustrated are specific to this case study, thus should not be seen as a generalised view of the industry. However, this study provides a foundation for further investigations to be carried out on the issues that surround modular construction in Ireland.

DISCUSSION

The data and subsequent analysis have been able to provide insight into the barriers that hinder the progress and implementation of modular construction in Ireland. Much of the existing literature in this area comes from sectors outside of Ireland; however, the data gathered did not coincide with all the literature reviewed. Nineteen key factors are derived from the interviews with "Lack of knowledge of modular construction in Ireland" and "Keeping a continuous schedule of projects" being among the most prominent.

Financial

A notable issue that is discussed at length is the continuity of pipeline of projects that the company must sustain. Rahman (2014) holds the view that the small market demand controls the capacity of manufacturers, thus effecting the cost of production. Fortunately, the company is currently delivering for a public sector contract that allows them to plan 6 months ahead. This provides them with a comfortable lead time to work to. Both interviewee B and C note that weekly meetings are held to ensure an appropriate number of projects are scheduled.

Table 1: Factors and Interview Results

		Interview A	Interview B	Interview C	Interview D	Interview E	Interview F
Financial	Capital cost of firm overheads	X		X		X	
	Capital cost of manufacturing	X		X		X	
	Variations in design prove costly					X	
	Keeping a continuous schedule of projects	X	X	X			
	Fixed price contracts not sustainable currently	X				X	
Design	Fire rating of the modules is difficult to achieve		X				
	Residential sector too intricate to enter		X	X			
	Certification system can impede design		X				
	Stakeholders do not like standardisation				X		
	Trying to achieve standardisation within design and manufacturing		X	X	X	X	
	Transport restricts design				X	X	
	Material selection restricts design				X	X	
Knowledge and Skill	Lack of knowledge of modular construction in Ireland	X	X	X		X	
	Stigma surrounding the modular system by clients		X	X		X	
	Skilled labour shortages		X			X	
Technology	BIM disruption with smaller jobs	X			X		
	BIM diffusion is low in Ireland				X		
Transport and Site	Restricted site access						X
	Underground services cause disruption to module installation						X

The manufacturing director explains that in times of low demand they begin manufacturing modules that are 50% finished and then stored until a contract is

initiated. The modules are then completed as per clients' specifications (Education, healthcare, pharmaceutical etc.). This allows manufacturing to remain at a stable rate and prevent a stop-start scenario as is the case with many construction projects. Furthermore, "Capital cost of manufacturing and firm overheads " was an issue that was raised. The participants state how this cost is a determining factor for a company to prosper or collapse. The case study uses their rental business as a backup if the cashflow from the modular division is reduced. This safety net is a unique scenario that other companies do not have the opportunity to obtain. Major costs for a modular company are the factory and machinery (Rahman 2014). The case studies facilities were already acquired reducing the capital cost, allowing them to focus on other key areas. Additionally, the current cost of materials is stated as a massive barrier, however, this may be seen as a barrier across the entire construction and manufacturing industry.

However, this cost rise has created a scenario where fixed price contracts are no longer suitable for projects. Interviewee B and E states that the fluctuations in materials and labour cost are too volatile to sign a fixed price contract. Furthermore, variations in the design are a costly expense which interviewee E expresses as a concern. The solution to this is a standardised design which uses the same materials and components continuously.

Design

Overall, seven issues are highlighted with regards to design. To begin with, interviewee B notes how the certification system in Ireland may inhibit their design capabilities. They are currently certifying the modules through the BCAR (Building Control Amendment Regulations) system which allows them flexibility within their design by certifying each individual element that they use in the module. They are considering achieving an NSAI Agrément cert, however this solidifies their design removing the flexibility they achieve with BCAR. The BCAR system must always be used for certification; however, an Agrément cert treats their module as a whole entity that has been tested accordingly and gives confidence to the client. This certification is expensive to ascertain and removes adjustability of the module. The participants note that they are weighing the positives and negatives of the certification and will decide on it once they develop their module further.

Furthermore, fire rating regulations in Ireland are enforced by fire officers in each county. Interviewee B notes how they encounter a scenario where different fire officers interpret the technical guidance documents (TGD's) differently regarding fire rating within the modules. This is difficult for the manufacturing division, as the fire rating is subjective to the fire officer in charge at each project. The difficulty arises when modules arrive to site and the fire rating is deemed unsatisfactory, leading to re-work, lost time, and additional costs. The frustration with trying to achieve a solid standardised design and construction system is heightened with this issue.

Standardisation within design and manufacturing is noted in the interviews as one of the key goals they want to achieve. Currently, interviewee C believes they provide too much flexibility to their clients, which curtails their modular process. If they could achieve a standardised design with modules, they would increase their productivity and construction time whilst reducing variations. This is intriguing as Zhai *et al.* (2020) notes the lack of flexibility is a barrier for modular construction.

However, it is apparent they are working out the trade-offs with design and manufacturing, determining which solution works to their business model best. It is

stated that the case study wants to ensure the client has control over their project, yet they want to limit variations and scenarios that increase construction time and cost. This is particularly difficult as the client's design teams are noted for not being in favour of standardised elements. Finally, interviewee B and C both agreed that the residential sector is too intricate to enter for them currently. The design and manufacturing of the modules would only be successful if it consisted of a large project with 3 or 4 house designs. This type of project permits economies of scale to be achieved. However, the manufacturing capacity required for this size of a project far exceeds what this case study company can obtain currently. The participants note how other sectors such as healthcare, pharmaceutical and commercial are much more applicable to their modular systems. This is ultimately due to the design of the modules, as these sectors utilise spaces with large open areas.

Knowledge and Skill

The case study participants continually state how the lack of knowledge surrounding modular from a client's perspective hinders their marketability. The main time advantage that modular offers is lost through lengthy discussions on what modular construction can achieve for the client. This view is seen in Azhar *et al.* (2013) study where the wrong conception of modular is established as a key barrier. Furthermore, the participants state that clients want to use modular as a construction technique, but they do not know why they are choosing modular. This creates extreme time delays and often removes the advantage of using modular construction in the first place. All participants agree that a government led approach, like the UK, would benefit the industry immensely. Interviewee's B, C, and E states that "Stigma surrounding the modular system" is a cause for concern. This issue is stated by Zhai *et al.*, 2013 study, as modular systems can be seen as options for the low-income demographic. It is stated that this is an issue which will develop for the company as they begin to service private contracts. Both interviewees A and B agree that they have witnessed clients assuming that these systems are "shoddy" and "flimsy". To counteract these perceptions, knowledge and education is required as is indicated in Hwang *et al.*, 2018 study where owners and developers do not fully understand the capabilities of modular construction.

Technology

Building Information Modelling is a process that the case study uses regularly in their design, manufacturing, and construction process. BIM 360 and Navisworks are the primary software's that are utilised within the company. Interviewee's A and D state that they experience disruption to their BIM process when servicing much smaller jobs in rural Ireland. This issue is highlighted by Wuni and Shen (2020) as they note the lack of synergistic information platforms challenge collaborative working among stakeholders. Interviewee's C and D states that BIM level 2 is not being achieved at all in their experience. Furthermore, BIM diffusion in Ireland is stated as extremely low, while the lack of in-house experience across architects and engineers is evident.

Transport and Site

Interviewee D describes that the fundamental barrier which restricts volumetric modular is the sizing of the modules. Bridge heights, road weight capacities and module sizes are the definitive constraints that reduce the design and constructability of volumetric modular. The design elements of the module also restricts its marketability. Hwang *et al.* (2018) note in their study that design is limited by transportation restrictions which is evident in the case study. The module cannot be

constructed from mass concrete as it would over the legal weight limit for haulage, however it must be a robust system that can undertake a significant amount of stress. Achieving this balance is challenging. Furthermore, Interviewee F states the difficulty in working with congested or restricted areas. Underground services prove troublesome for the installation, while organising crane and haulage is a task that requires significant planning among all stakeholders.

CONCLUSIONS

This exploratory study focuses on the barriers that impede modular construction in Ireland with regards to SME's. The case study provides an essential glimpse into the industry and the constraints that they encounter. Even though traditional construction is still thriving in Ireland, modular techniques are on an upwards trend. From the analysis carried out, nineteen key constraints are identified with "Lack of knowledge of modular construction in Ireland" and " Keeping a continuous schedule of projects " being among the most highlighted. The case study data suggests that the problems associated with utilising modular construction are varied and subjective to the company. The company in question is unique due to them being involved in prefabrication for the past 40 years, allowing them to ascertain valuable knowledge about the industry. The interviews provide insight into key concerns and limitations that are subjective to them, such as their efforts to achieve fire rating or their intention to obtain an Agrément certificate and the ramifications that may have on their design capabilities.

Despite these issues, one of the main concerns that was highlighted was the lack of knowledge and education Ireland obtains with regards to modular construction and its potential. It is recommended that to combat this lack of knowledge, companies such as this case study should target educational institutions. Workshops that provide essential information on what modular construction is, its capabilities, and the issues surrounding it, would help overcome many of the issues highlighted above. Overall, the key contribution of this study highlights that many of the issues faced are subjective and complex to the firm, however, this study only focuses on one company, reducing the overall geographical area covered. A wider array of participants and case studies is necessary to obtain a better analysis of the Irish modular industry which is the next stage of the research. The data provided in this study provides support for further research to evaluate the modular industry. Furthermore, this study aims to provide insight for academia and industry into the barriers that are constraining the modular industry in Ireland.

REFERENCES

- Azhar, S, Lukkad, M and Ahmad, I (2013) An investigation of critical factors and constraints for selecting modular construction over conventional stick-built technique, *International Journal of Construction Education and Research*, **9**(3), 203-225.
- Blismas, N and Wakefield, R (2009) Drivers, constraints and the future of offsite manufacture in Australia, *Construction Innovation*, **9**(1), 72-83.
- Brooks, T, Spillane, J, Tansey, P and Hendron, C (2016) The impact of the recent economic recession on the operation of the NEC contract in Northern Ireland, *Construction Management and Economics*, **34**(6), 393-417.
- Cheng, D and Ma, J (2020) Research on the restrictive factors of the development of Chinese prefabricated buildings, *IOP Conference Series: Earth and Environmental Science*, **531**(1), 012044.

- Hwang, B, Shan, M and Looi, K (2018) Key constraints and mitigation strategies for prefabricated prefinished volumetric construction, *Journal of Cleaner Production*, **183**, 183-193.
- Jaillon, L and Poon, C (2010) Design issues of using prefabrication in Hong Kong building construction, *Construction Management and Economics*, **28**(10), 1025-1042.
- Linner, T and Bock, T (2012) Evolution of large-scale industrialisation and service innovation in Japanese prefabrication industry, *Construction Innovation*, **12**(2), 156-178.
- Mao, C, Shen, Q, Shen, L and Tang, L (2013) Comparative study of greenhouse gas emissions between off-site prefabrication and conventional construction methods: Two case studies of residential projects, *Energy and Buildings*, **66**, 165-176.
- Ministry of Housing, Communities and Local Government (2019) *Government Response to the Housing, Communities and Local Government Select Committee Report on Modern Methods of Construction*, Crown Copyright: London, UK.
- Pan, Y, Wong, F and Hui, E (2010) Application of Industrialized Housing System in China: A Chongqing Study, *Computational Risk Management*, **19**(3), 161-168.
- Polat, G (2008) Factors affecting the use of precast concrete systems in the United States, *Journal of Construction Engineering and Management*, **134**(3), 169-178.
- Rahman, M (2014) Barriers of Implementing Modern Methods of Construction, *Journal of Management in Engineering*, **30**(1), 69-77.
- Central Statistics Office (2014) Available from: <https://www.cso.ie/en/releasesandpublications/ep/p-bii/bii2014/sme/> [Accessed 3 April 2022].
- Enterprise Ireland (2022) Available at: <https://www.enterprise-ireland.com/en/about-us/our-clients/sme-definition.html> [Accessed 3 April 2022].
- Taylor, M (2010) A definition and valuation of the UK offsite construction sector, *Construction Management and Economics*, **28**(8), 885-896.
- Taylor, M (2020) A definition and valuation of the UK offsite construction sector: Ten years on, *International Journal of Construction Management*, 1-9.
- Wuni, I and Shen, G (2020) Barriers to the adoption of modular integrated construction: Systematic review and meta-analysis, integrated conceptual framework and strategies, *Journal of Cleaner Production*, **249**, 119347.
- Zhai, X, Reed, R and Mills, A (2013) Factors impeding the offsite production of housing construction in China: An investigation of current practice, *Construction Management and Economics*, **32**(1-2), 40-52.