UK COMMISSION FOR EMPLOYMENT AND SKILLS

Technology and skills in the Construction Industry

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Technology and Skills in the Construction Industry

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Foreword

The UK Commission for Employment and Skills is a social partnership, led by Commissioners from large and small employers, trade unions and the voluntary sector. Our ambition is to transform the UK's approach to investing in the skills of people as an intrinsic part of securing jobs and growth. Our strategic objectives are to:

- Maximise the **impact** of employment and skills policies and employer behaviour to support jobs and growth and secure an internationally competitive skills base;

- Work with businesses to develop the best market solutions which leverage greater investment in skills;

- Provide outstanding labour market intelligence which helps businesses and people make the best choices for them.

The third objective, relating to intelligence, reflects an increasing outward focus to the UK Commission's research activities, as it seeks to facilitate a better informed labour market, in which decisions about careers and skills are based on sound and accessible evidence. Relatedly, impartial research evidence is used to underpin compelling messages that promote a call to action to increase employers' investment in the skills of their people.

Intelligence is also integral to the two other strategic objectives. In seeking to lever greater investment in skills, the intelligence function serves to identify opportunities where our investments can bring the greatest leverage and economic return. The UK Commission's third strategic objective, to maximise the impact of policy and employer behaviour to achieve an internationally competitive skills base, is supported by the development of an evidence base on best practice: "what works?" in a policy context.

Our research programme provides a robust evidence base for our insights and actions, drawing on good practice and the most innovative thinking. The research programme is underpinned by a number of core principles including the importance of: ensuring 'relevance' to our most pressing strategic priorities; 'salience' and effectively translating and sharing the key insights we find; international benchmarking and drawing insights from good practice abroad; high quality analysis which is leading edge, robust and action orientated; being responsive to immediate needs as well as taking a longer term perspective. We also work closely with key partners to ensure a co-ordinated approach to research.

This project explores the skills required to meet the demands created by existing and emerging technologies in construction. The main focus is on innovative Modern Methods of Construction (MMC), particularly offsite construction - with the aim of identifying and understanding opportunities and challenges for the future. This includes the longer term skills needed to adopt emerging or future technologies and to realise the potential of these technologies for diversification and business growth. The research will be a useful resource in guiding employers in anticipating how the demand for technology driven skills is likely to develop in the future and in investing in training to meet these demands.

Sharing the findings of our research and engaging with our audience is important to further develop the evidence on which we base our work. Evidence Reports are our chief means of reporting our detailed analytical work. All of our outputs can be accessed on the UK Commission's website at www.ukces.org.uk

But these outputs are only the beginning of the process and we are engaged in other mechanisms to share our findings, debate the issues they raise and extend their reach and impact.

We hope you find this report useful and informative. If you would like to provide any feedback or comments, or have any queries please e-mail info@ukces.org.uk, quoting the report title or series number.

Lesley Giles

Deputy Director

UK Commission for Employment and Skills

Table of contents

Foreword iii

Table of contents v

Tables and figures viii

Glossary ix

Executive Summary x

1. Introduction 1

1.1 Definition of high level skills 2

1.2 Aims and objectives of the study 3

2. The construction industry 5

2.1 Economic position 5

2.2 Modern Methods of Construction (MMC) 6

2.3 Offsite is not new 7

2.4 Categories of offsite construction 8

3. Offsite sector profile 10

3.1 Size and value of the offsite construction sector 10

3.2 Potential for future growth of the offsite construction sector 12

3.2.1 Quality and safety 12

3.2.2 Time and cost reduction 13

3.2.3 Offsite methods for home building 13

3.2.4 The energy efficiency and low carbon agenda 13

3.3 Risk factors for the offsite sector 14

3.3.1 Typical SME business models 14

3.3.2 Bringing products to market 15

3.3.3 The impact of the economic downturn 16

3.3.4 Overseas competition 18

3.4 National differences and geographic 'hubs' 18

4. Skills for MMC and offsite construction ... 21
4.1 Skills, knowledge and behaviour needs for offsite ... 25
4.1.1 Knowledge, mutual understanding and collaboration ... 26
4.1.2 Marketing and business case development ... 27
4.1.3 Project management ... 30
4.1.4 Information technology ... 31
4.1.5 Planning and design ... 33
4.1.6 A whole life approach ... 34
4.2 The impact on the skills supply chain ... 36
5. Occupations and job roles ... 38
5.1 Job roles in offsite ... 39
5.2 Demand for job roles for offsite ... 40
5.3 Supply of offsite roles ... 41
5.4 The impact of offsite on job roles ... 41
5.4.1 Evolution of job roles ... 41
5.4.2 Existing priority roles ... 42
5.4.3 Hybrid roles ... 44
5.4.4 New roles ... 44
5.5 The impact on lower level occupations ... 45
5.5.1 Entry routes and the skills pipeline ... 47
6. Qualifications and Training ... 48
6.1 Perceptions of existing training and qualification provision ... 48
6.1.1 Disconnection between industry and academic education ... 49
6.1.2 Fragmented provision ... 50
6.1.3 Limited apprenticeship provision ... 50
6.1.4 Time and economic pressures ... 51
6.1.5 Limited understanding of offsite training needs ... 51
6.1.6 Resistance to change ... 52
6.2 Gaps in training and qualifications ... 52

6.3 Responding to the issues 53

7. Summary 57

8. Implications 61

8.1 Closer collaborative relationships 61

8.1.1 Stimulating demand 62

8.1.2 Training and qualifications 62

8.1.3 Careers information 62

8.1.4 Continuing Professional Development 63

Appendix A: Methodology 64

Appendix B: Technologies 68

Appendix C: Existing Provision 77

Appendix D: Case Studies 81

Bibliography 92

Tables and figures

Figure 1: Four main categories of offsite construction.. 8
Table 1: Estimated potential for offsite construction to increase by 2016.............................. 12
Figure 2: Ideal mix of 'front-loaded' skills offsite 24
Figure 3: Skills, knowledge and behaviours needed for MMC and offsite construction 25
Figure 4: Core skills differences between offsite manufacturing and onsite assembly........ 36
Figure 5: Primary, secondary and tertiary job roles required for offsite construction.......... 39
Case Study 1: Straw bale construction, Modcell and the University of Bath 81
Case Study 2: Skills needs for offsite timber frame construction 84
Case Study 3: Job roles required for offsite construction in the concrete sector 88

Glossary

Building Information Modelling (BIM)	An IT package facilitating management of, and collaboration within, the construction process. The technology enables efficient coordination of the programming, designing, specifying and building processes. The use of BIM is mandatory for all government projects from 2016.
Computer Aided Design (CAD)	A computer system to facilitate the creation and modification of a design.
Lean manufacturing	A process aimed at increasing market share, whilst minimising the resources used – an approach generally accepted as being pioneered in Japan
Modern Methods of Construction (MMC)	A term spanning a broad range of construction technologies that are used to improve both product and process in construction.
Pre-fabricated structure	A building consisting of factory built components or units.
Micro-generation	The production of heat or electricity on a small scale, usually by individual households.
Small Medium Enterprise (SME)	An enterprise employing fewer than 250 employees.[1]

[1] This study's consideration and analysis of SME's is consistent with this definition.

Executive Summary

'Technology and Skills in the Construction Industry' details the findings of a study into the role of technology in driving high level skills needs in the construction industry, with a specific focus on offsite construction.[2] The construction industry is one of the most important sectors to the UK economy, with 12 per cent of construction taking place offsite (Taylor, 2010).

This report is one of a number of studies commissioned with the purpose of understanding the skills needs of Government priority sectors.[3] This is essential in order to ensure appropriate responses in relation to tackling skills gaps and shortages, so that the UK is best placed to compete in a global marketplace.

The research used a mixed approach of depth interviews with academics, industry representative bodies, employers, trade associations and professional institutes, combined with a literature review and roundtable discussion events.

Offsite construction

Offsite construction is a method of building used for thousands of years that can be traced as far back as Roman times but is perhaps most commonly associated with post-war rebuilding, in the form of pre-fabricated building.

Today offsite construction, one of a number of 'Modern Methods of Construction' (MMC), is increasingly technology driven. Currently, there exists no universal definition of offsite construction but it is widely recognised as comprising four main types of assembly which range from small scale items such as light fittings; large scale modules and panelised systems; units of fully enclosed space (i.e. individual rooms); to complete buildings.

The concept of offsite is closely associated with manufacturing and draws on principles which seek to achieve improvements in quality, reductions in waste and improvements in the efficiency of the overall build process.

[2] This study uses a broad definition of high level skills, based on national qualification levels: level 4 and above of the Qualifications and Credit Framework in England and level 8 and above of the Scottish Qualifications and Credit Framework.
[3] Construction is a priority in the Department for Business Innovation and Skills' Industrial Strategy; Finance and Business Services (architecture element) is a Scottish Government Key Sector; Construction is a Welsh Government Key Sector.

Profile and importance

Due to the lack of a universal definition of offsite, estimating the scale and value of the offsite sector is extremely challenging. The most recent estimates put the value of offsite construction at around £1.5bn, with a potential to achieve as much as £6bn. Projections for 2013 (developed in 2009) suggest the current value of the sector as likely to be 7 per cent of total construction output (Gambin *et al.,* 2012). In total, the construction sector currently contributes nearly £90bn to the UK economy (BIS, 2013). A share of 7 per cent would equate to over £6bn.

The offsite market is mainly split between small, innovative developers typically based around a particular technology or product, and large construction companies.

The current geographic distribution of offsite construction is uneven, with regional 'hubs' of expertise and activity: Scotland is recognised as a major hub of timber frame assembly (most notably in the house-building sector), along with parts of Wales; a large concentration of offsite construction is to be found in the South of England, mostly on large-scale infrastructure projects such as schools, hospitals, hotels and student accommodation. In the latter region there is generally greater take up of offsite construction methodologies; more so for infrastructure projects, commercial buildings, schools, hospitals and student accommodation than perhaps large scale domestic builds.

The potential uptake and growth of offsite construction is heavily influenced by a number of factors some facilitating, and others impeding the level of market demand.

Currently, weak demand has supressed the market for offsite, combined with some wider industry reluctance to adopt certain innovative technologies, with resistance from financiers and insurers to invest in what are seen as new, untested technologies. Factors such as national/regional differences and related local demand, availability of materials, access to skills and training, foreign competition and capacity to bring products to market all have, and will continue to have, an impact on growth, and its rate. Fully harnessing the potential of offsite construction relies on achieving the critical mass required to realise arguably the most attractive benefits of time and cost savings.

There are however notable drivers influencing the uptake of offsite technologies, particularly in relation to the need for higher volume output in home building and the impetus of the low carbon agenda. Offsite is an opportunity to more tightly control costs, respond to government targets for Building Information Modelling (BIM) and energy efficiency, increase efficiency in the build process and improve quality (including site health and safety).

One of the key advantages of offsite construction is the greater efficiency and quality of the build process. The fit out of buildings can be done in the factory setting, modular steel or timber frame systems can be adjusted for performance and cladded offsite.

The use of offsite technologies can encourage a greater diversity of people into the sector, including more young people, due to weatherproof working conditions and a reduction in the use of manual labour.

It is extremely challenging to forecast exactly when growth in the offsite sector might happen, over the short, medium or long term, and when demand for certain skills and job roles might be realised and in what quantity. Nevertheless, there are very real opportunities for the sector to compete globally in an already buoyant international arena (currently dominated by Germany and Austria), with legitimate export potential.

Furthermore, there is encouraging scope for economic growth in the manufacturing sector. The obvious links between manufacturing and construction in relation to offsite may offer greater potential for the construction sector to benefit from such growth.

Skills and knowledge for offsite construction

The greater uptake of offsite construction is likely to have a gradual impact on existing skills and job roles although the requirement for appropriate training and qualifications is likely to be more immediate.

Core, higher level skills and knowledge needs for offsite can be categorised as:

- collaboration between disciplines;
- marketing and business case development;
- project management;
- information technology (including BIM skills and knowledge of automated design tools);
- planning and design;
- a whole life approach, considering the whole life cycle of the building including repair and maintenance requirements.

There is debate within the industry surrounding the potential of offsite construction to reduce skills demands and needs made by the construction process, as the extent of demand for traditional skills is reduced (or arguably displaced) by manufacturing and assembly activities.

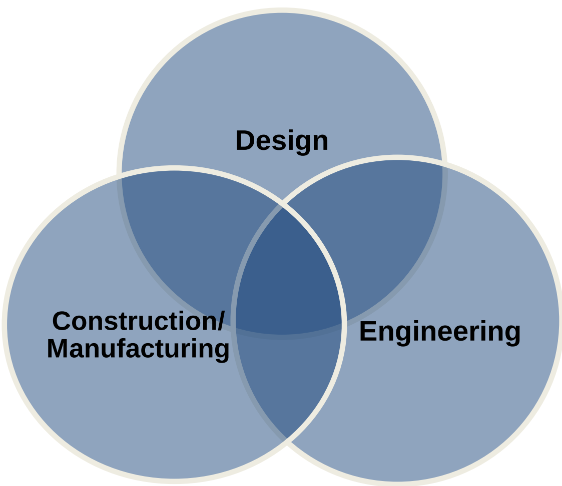
The introduction of what is essentially a manufacturing process into the construction operation has led to a debate over the extent to which this transition may result in either a multi-skilling or de-skilling scenario for the existing workforce. At a lower level (for example traditional ‘trade’ roles such as carpentry and plastering), it is suggested that skills will likely remain unchanged, but the context in which they are applied will be different; essentially, a shift to both an onsite and offsite construction environment.

The most significant change is predicted to occur for those in higher level roles, with the skills profile of professional occupations evolving over the medium to longer term to embrace multiple different skills and areas of knowledge. This will necessitate a change from traditional ‘silo-based’ approaches to skills and professional disciplines.

Progressively closer integration between core disciplines and skills sets is predicted over the medium to longer term, underpinned by a requirement for a mutual understanding and appreciation of other roles and their contribution to the build process.

As the offsite build process becomes more integrated with manufacturing, the management of that process and of the interface between the offsite and the onsite environments becomes ever more critical. Skills in design and an understanding of engineering principles also become more important. The diagram below sets out the predicted increased integration between design, construction, manufacturing and engineering disciplines:

Figure A: Predicted increasing integration between different disciplines



Occupations and job roles in offsite construction

Currently, job roles in offsite can be categorised into three groups: primary, secondary and tertiary.

- Primary job roles encompass those involved in the design and delivery of offsite projects, such as project management, logistics, marketing and sales.
- Secondary roles comprise typically 'trade' specific disciplines involved in assembly.
- Tertiary job roles associated with providing supporting functions (but of no less importance than primary and secondary roles) include the provision of finance, insurance and procurement, for example.

Project management roles, schedulers, design staff and engineers are currently most in demand for offsite; Computer Aided Design (CAD) specialists and quantity surveyors are also sought after. The use and prevalence of architects is somewhat less usual in offsite than in traditional onsite construction, with a preference for design engineers, also bringing in skills in IT, predominantly in CAD and BIM.

Over the medium to long term, job roles are anticipated to evolve rather than undergo a radical switch, although this does not imply that existing roles will be unaffected. Design and architecture roles; engineering; BIM modelling and supervisory/project management roles are considered to be the most important and most liable to change.

Qualifications and training

The current training and qualification offer for offsite is considered to be largely inadequate due to a range of factors that have resulted in fragmented provision and a situation where employers create their own, bespoke, in-house training. There are many reasons for this, research participants attributed it to:

- a general disconnection between industry and training providers, and industry and academia;
- the bespoke nature of many offsite systems which makes the development of consistent provision extremely challenging;
- a range of cultural issues faced by employers, such as lack of time and money to invest in training, coupled with a limited understanding of where skills and knowledge gaps in offsite lie.

Deficiencies within the current training offer, in terms of content, have been identified as 3D drawing; site supervision; logistics; BIM and an understanding of design technologies and materials used in offsite.

The table on the following page summarises some of the main influencing factors on offsite construction, along with the associated impacts on future skills, knowledge and qualifications as well as job roles. The content of the table has been drawn together from an analysis of the research findings and is not intended to be exhaustive.

Drivers/influencers on the uptake of offsite	Opportunities of offsite	Threats to the use of offsite	Impact on future skills, knowledge and training/qualifications	Future impacts on job roles
The energy efficiency and sustainability agenda The housing shortage – in both private and social housing The economic climate – reducing costs UK Government commitments: • Use of BIM on all centrally procured Government contracts from 2016 • Priority sector in England, Scotland and Wales • Improvements in export Ageing workforce Emerging technologies	Attracting young people into the sector due to weatherproof working conditions Competing in a global market Contributing to environmental and sustainability targets Responding to housing demand More widespread acceptance of offsite methods for commercial projects (largely in the South of England) Realising cost savings through reduced build time Improving quality Improving health and safety Increasing efficiency and reducing costs in the construction process Integration of roles and collaborative working	Negative associations amongst the public with 'pre-fabricated' structures Weak market demand Gaining accreditation and recognition of new technologies Timelag in new technologies reaching the market Lack of collaboration between academia and industry Fragmented training provision 'Patchy' geographical distribution of offsite industry Achieving the critical mass in production to realise cost-savings Risk averse financiers/ investors Reluctance of wider industry to adopt MMC/offsite International competition Difficulties in forecasting growth and uptake of offsite technologies	'Hubs' of expertise and inconsistent training offer nationally (UK-wide) Technologies need to be 'mainstreamed' in order to develop consistent training packages Requirement for high level skills in marketing, technical sales, influencing and negotiating Better understanding of the design/manufacture/construction interface Highly developed skills in project management, scheduling and planning Wider adoption of a 'whole life approach' to structures	Greatest impact of offsite on existing job roles is expected to concern: • Site Supervisor • Designer • Architect • Structural Engineer • Planner • BIM Modeller Future demand for: Schedulers, Site Labourers, Project Managers, Quantity Surveyors, Design office staff including BIM Modellers, Engineers, CAD Specialists Hybrid roles may result in overlap between managerial and professional levels; a technical sales role will require an overlap between commercial and technical skill All disciplines increasingly expected to work collaboratively.

Implications for government and the sector

Closer collaborative relationships

Greater collaboration between industry and academia, notably in relation to influencing the design of training and qualifications, could enable these to become truly industry-led. In the short-term, consideration could be given to creating an Offsite Skills Network bringing together academia, research institutes and industry with the purpose of sharing knowledge and establishing an interface between innovation and commercial application.

Stimulating demand

Trade Federations and Professional Bodies may wish to work collaboratively on programmes to educate investors, industry stakeholders and home-owners. There is an appetite and interest in technologies amongst consumers. The development of positive case studies could help counteract any negative perceptions in relation to offsite and stimulate consumer demand.

Training and qualifications

A culture of ‘multi-skilling’ could be embedded at training stage. For instance, training could seek to equip students with a broader skills and knowledge base about offsite enabling application of these core skills and knowledge to different settings, materials and systems. Training and education providers could consider approaches to offsite training provision in Austria and Germany and identify good practice which can be transferred to the UK.

Careers information

Careers information, advice and guidance to those seeking opportunities in the construction sector that includes consideration of offsite construction job roles could help offer clear pathways to higher level occupations as well as promoting offsite to a greater diversity of people, including young people.

Continuing Professional Development

Continuing Professional Development (CPD) could be a potential solution to top up gaps in skills in the short time. The construction industry is more likely to be able to take advantage of CPD that can be delivered flexibly (for example via webinars outside of core working hours), and that is not cost prohibitive.

1. Introduction

The UK Commission believes that a new approach to skills is needed, which is focused on the needs of employers; one which is based on ambition and innovation. A pivotal part of this agenda is the employer ownership of skills, facilitating a sea change in the way that the skills system works, by empowering employers, their supply chains and other key partners to develop the skills they need to succeed.[4]

A steady stream of skilled labour is required, at all levels of the labour market, to realise the country's full economic potential. Understanding skills needs and gaps is therefore key.

The construction industry is one of the most important sectors to the UK economy and one of eight sectors addressed in the Government's first growth review in 2011. Following this, the UK Government's recently published Construction Industrial Strategy, developed in partnership with the industry, sets out an ambitious vision for the construction industry.

The strategy envisages dramatic improvements in performance by 2025 – including a 33 per cent reduction in both the initial construction cost and the whole life cost of built assets; 50 per cent faster delivery of construction projects; a 50 per cent improvement in exports; a 50 per cent decrease in greenhouse gas emissions; and a 50 per cent reduction in the current £6 billion trade gap between construction imports and exports. It sees these developments as being underpinned by the evolution of a more technologically advanced industry that is:

- 'smart': efficient and technologically advanced, with a highly skilled and diverse workforce;
- 'sustainable': with world-leading export performance in green technologies and materials;
- able to deliver 'growth': with the UK's share of global construction markets expanding substantially (H M Government, 2013).

This represents a major opportunity for the construction industry to further embrace technological change and innovation. Indeed, a large number of skills priorities are recognised as being driven by the use or development of technology, whether this is the evolution or adaptation of existing technologies, or the innovation and development of new technologies.

[4] www.ukces.org.uk/ourwork/investment/employer-ownership

Industries associated with the use of technologies and innovative work processes make a significant economic contribution (OECD, 2007).

In the construction industry, the use of technologies is arguably most closely associated with environmental technologies and with sustainability more generally, in reducing reliance on carbon fuels through alternative energy production (micro-generation) and cutting energy consumption by the design and construction of more efficient buildings. The building process itself is a third area in which technologies can be harnessed.

Modern Methods of Construction (MMC) have the potential to introduce greater efficiencies into the build process, chiefly through innovations in building design and management, for example in adoption of Building Information Modelling (BIM), and in offsite construction processes.

The application of technology and innovation, in the form of BIM, MMC and offsite production, is expected to have an important role in realising the UK Government's vision for the construction industry. BIM in particular is identified as a key driver, the Construction Industrial Strategy stresses the major progress being made on the implementation of BIM, which will become compulsory for all public sector construction projects from 2016 onwards.

An understanding of the skills required to harness these technologies and achieve their full potential is therefore critical. This study is one of a number commissioned by the UK Commission for Employment and Skills with the purpose of understanding, in depth, the skills needs of Government priority sectors.

This report is intended to add to the existing evidence base, such as the *Sector Skills Insight* (Gambin *et al.,* 2012) and *Sector Skills Assessment for Construction* (Breuer, 2012) and focuses specifically on the higher level skills associated with offsite construction.

1.1 Definition of high level skills

Skills needed to drive the development or use of technology are reported primarily at higher occupational levels, such as managerial, professional and associate professional and technical occupations. These 'high level' job roles were the focus of this study.

Similar job roles and job titles can relate to quite different remits and responsibilities. Therefore, for the purpose of this study, a broad definition of 'high level skills' was used, based on national qualification levels. Job roles and disciplines within scope of the study included those for which a 'high level' qualification is typically required. 'High level' is usually defined as:

- Level 4 and above of the Qualifications and Credit Framework (QCF) in England;
- Level 8 and above of the Scottish Qualifications and Credit Framework (SCQF) in Scotland.

This covers such qualifications and programmes as Higher Apprenticeships, Foundation Degrees, Higher National Diplomas (HNDs), Degrees and Postgraduate Qualifications for example.

Our definition of high level skills was not based exclusively on qualification attainment however; experiential learning and Continuing Professional Development (CPD) are also valid forms of skills development at a higher level and were recognised as such throughout the research.

1.2 Aims and objectives of the study

This study's main area of interest is innovative methods of construction, namely offsite construction. This method of construction combines traditional methods of construction, in terms of fitting, finishing and installation with innovative new technologies, methods and processes undertaken away from the construction site.

The overarching aim of this study is to understand the requirements for high level (and supporting) technical skills in the construction industry and it is underpinned by a number of objectives, to:

- understand in depth the technologies in question and the associated skills required in order to harness their future potential;
- understand the impact that future skills needs might have on the occupations involved, and the relationships between them.

In addition, the study focused on identifying interdependencies between technologies and other skills drivers, such as regulation, competition and consumer demand, along with opportunities and challenges for economic recovery and growth posed by drivers and influencing factors in the short, medium and long term.

The approach followed the supply chain of innovative methods of construction as it filters to different 'tiers', starting with the **'innovators'** of new technologies (such as Universities and academics), the **'developers'** of those technologies (such as manufacturers and large employers) and the **'users'** (such as, designers, architects, construction firms and sub-contractors). Interviewees were drawn from each group or tier. Strategic stakeholders, such as Government officials, were also consulted as part of the research.

The research used a mixed methodology of 50 depth interviews, a detailed literature review of over 100 sources and three roundtable discussions in England, Scotland and Wales.

A fourth roundtable was planned for Northern Ireland, however it became apparent as the research progressed that offsite construction activity here is limited and therefore sufficient recruitment was not possible. Appendix A provides further detail on the study methodology.

In addition Appendix D sets out three case studies showcasing innovative offsite technologies, the associated skills needs and job roles.

2. The construction industry

- Modern Methods of Construction (MMC) span a broad range of technologies including offsite construction or offsite manufacture. Despite the common use of this term, offsite is not a new or even recent innovation.

  Whilst it is important to distinguish between the construction and manufacturing sectors, it should be noted that the line between the two in relation to offsite is somewhat hazy, with some areas of obvious overlap or close association.

- Furthermore there is no one standard definition of offsite, other than broad agreement on the types of components and assemblies used, therefore one person's understanding of offsite may differ from another's.

- The construction sector is dominated by small and medium-sized enterprises (SMEs) and micro-businesses, and has been subject to recent market decline, placing these smaller organisations in a more vulnerable position.

- There is encouraging scope for economic growth in the manufacturing sector, already one of the four largest sectors in the UK economy, and expected to grow further over the period to 2017. The obvious links between manufacturing and construction in relation to offsite may offer greater potential for the construction sector to benefit from such growth.

2.1 Economic position

The construction industry as a whole is dominated by small and medium-sized enterprises (SMEs), with small and micro businesses accounting for approximately 95 per cent of the sector. Large construction companies are typically major contractors on large-scale building and infrastructure projects, with many smaller companies working in a sub-contracting capacity. Larger companies, although constituting a very small proportion of the number of enterprises operating in the sector, conduct a disproportionate share of the work by value (Breuer, 2012).

The construction industry is continuing to experience a decline, with the latest estimates placing the volume of construction output at its lowest level since the last quarter of 1998 (ONS, 2013). For the first quarter of 2013 almost all sub-sectors of construction experienced decline, with the exception of private housing repair and maintenance (an increase of 0.4 per cent).

Similarly, many other sectors of the UK economy, including three of the four largest (finance and insurance, professional and other provider services, and public services) are projected to perform poorly over the period to 2017, compared to their performance over the five years to 2007 (CITB, 2013).

The manufacturing sector, however, also one of the four largest sectors of the UK economy, is expected to buck this trend. Manufacturing grew in the five years to 2007, and is predicted to continue to show improvement in the period to 2017 (CITB, 2013).

The current *UK Sector Skills Assessment* states that 12 per cent of construction takes place offsite and links closely with the manufacturing sector (Gambin *et al.,* 2012). The implications for the construction sector as a whole could therefore be significant over the period to 2020.

2.2 Modern Methods of Construction (MMC)

'Modern Methods of Construction' is a phrase that encompasses a broad range of technologies that include offsite construction, or offsite manufacture. The terms are often used interchangeably in much of the literature. The British Research Establishment (BRE) defines MMC as "*a range of processes and technologies which involve prefabrication, offsite assembly and various forms of supply chain specifications"* (BRE, date unknown).

MMC has been described as including all "*new products and technologies"* that result in "*delivery methods which set out to improve product and process"* (CIC, 2013). MMC also includes innovative approaches that are intended to increase the speed and efficiency of onsite construction.

MMC is generally acknowledged as a means of reducing reliance and emphasis on onsite activity, whether that be through the adoption of offsite manufacturing techniques wholly, or in part, for example through the use of pre-assembled components with the aim of adding value to the construction process.

Offsite construction has been concisely defined in a review by the Construction Industry Council (CIC) as a "*delivery method that adds substantial value to a product and process through factory manufacture and assembly intervention";* it further refines this definition by considering offsite manufacturing as "*an approach to process in which the construction value added onsite is less than 40 per cent of the final construction value at completion"* (CIC, 2013).

Although offsite construction is most closely associated with timber construction, it can also make use of numerous other materials including steel, block masonry and concrete.

Pre-stressed concrete element, although often classed by contractors as a 'traditional' form of construction, can legitimately be regarded as an offsite approach (Goodier and Gibb, 2005).

2.3 Offsite is not new

Offsite construction methods have been traced back as far as the practices of Roman military engineers, as revealed by archaeology and described by the architect Vitruvius.

Recent research on English medieval houses suggests that in many cases they were constructed of timber that was fully cut and shaped offsite, usually in the forest where it was felled, and then transported to the construction site.[5] It is also known that pre-fabricated wooden structures were exported from the British colonies on the Eastern seaboard of North America to the Caribbean in the seventeenth and eighteenth centuries. By the later eighteenth century, high value components of buildings, often decorative details which would otherwise have to be carved or cast by specialist artisans, were also mass-manufactured. Examples include sculptural details from the Coade factory, papier mâché decorations for interiors, and decorative fanlights for overdoor windows. [6]

In the nineteenth century, Great Britain led the world in the use of pre-fabricated building components and even entire buildings. One of the most remarkable surviving structures, again in the Caribbean, is the Old Naval Hospital in Port Royal, Jamaica, dating from 1819. The frame of the building is made from pre-fabricated cast iron units manufactured in Bradford, and has survived intact through numerous hurricanes and a major earthquake (Crain, 1994).

The development of 'kit' houses was widespread in the development of the North American West in the first half of the twentieth century, after W.J. and O.E. Sovereign realised that the principles used for boat kits made of pre-cut and finished timber components could be applied to domestic housing. Their own company, Aladdin Homes, pioneered the business model, which was then taken up by major mail order catalogue companies such as Sears Roebuck and Eaton's who sold 'mail order homes' by the thousand. The attractions of such methods included lower cost, higher quality, less waste, and faster build speed.

[5] http://www.buildingconservation.com/articles/timberframedbuildings/timberframedbuildings.htm
[6] Coade stone is composed of clay fired in a kiln at a very high temperature. During the 18th century it was used extensively on buildings and for statuary.

Pre-stressed concrete construction in the post-war period was widespread, spurred principally by the requirement for up to 25 per cent less steel in its construction for flexural reinforcement – a material that was in short supply. Applications of pre-stressed concrete quickly developed from civil engineering projects, most notably in bridge building, to more widespread use in the manufacture of roof beams from the late 1940s (Burgoyne, 2005).

From the 1960s, due to availability and relative cost efficiency, steel structures became more commonplace and found greater favour amongst house builders. Today fabrication of individual steel elements can be undertaken offsite using well-controlled and regulated factory conditions, and delivered to sites as and when needed. Steel components can be pre-assembled or fabricated into modules offsite or at low levels onsite, reducing the requirement for working at height.

2.4 Categories of offsite construction

Today, although there are variations in the way that offsite construction is defined and described, there are generally accepted to be four main categories (Gibb et al., 2013).

Figure 1: Four main categories of offsite construction[7]

Component sub-assembly	• relatively small scale items that are invariably assembled offsite, such as light fittings, doors, windows, door furniture.
Non-volumetric preassembly	• large category of items that the designer has chosen to assemble in a factory before installation; units do not enclose usable space; applications may be skeletal, planar or complex e.g. panel systems; cladding panels; above ceiling service modules.
Volumetric pre-assembly	• units that enclose usable space that are then installed within or onto a building or structure; typically fully finished internally, e.g. toilet/bathroom pods, plant rooms.
Complete buildings	• units that enclose usable space and actually form part of the completed building or structure (units may or may not incorporate modular coordinated dimensions); typically fully factory finished internally (and possibly also externally), e.g. edge of town hotel or restaurant facilties, multi-residence housing.

[7] The Housing Corporation lists its own definition of what constitutes MMC (which are largely offsite methods and technologies), and which are not significantly different from those described above .

Additionally, hybrid methods may use elements of panelised and modular construction techniques. All these approaches can be applied to different building materials, of which the most important are timber, steel and concrete.

Further detail on the individual technologies associated with offsite construction is provided in Appendix B.

The concept of offsite construction ties in neatly with a number of new and 'innovative' concepts such as Open Building Manufacturing as identified by Echert et al in a 2007 article.[8] The approach to Open Building Manufacturing is reported as requiring more collaborative relationships perhaps than are required for 'traditional' building methods, is knowledge driven and places a real emphasis on customer focus (Echert *et al.,* 2007).

Aside from new innovations and technologies, offsite is recognised as having a very strong potential to facilitate the uptake and mainstreaming of low carbon and energy efficient buildings by integrating timber or light steel frames and/or thin joint blocks into the build process. The potential of structured insulated panels (SIPs) and specific technologies such as combined heat and power (CHPs) units is also acknowledged. Realising such potential is of course heavily reliant on appropriate skills and knowledge being possessed by the workforce, at all levels.

Offsite construction methods can be applied as readily to traditional design as to modern buildings – as shown by the recent move of William E. Poole, a well-known designer of high-end traditional, classical revival houses in the USA into customised offsite production.[9]

The processes involved in building offsite structures have been described by Buildoffsite (an industry-wide campaigning organisation promoting uptake of offsite techniques by UK construction) as embodying three main techniques:

- **Design for Manufacture and Assembly (DFMA):** essentially, to improve quality through efficiency;
- **Lean Production:** the reduction of waste;
- **Building Information Modelling (BIM):** a cost-effective means of planning, designing and controlling building projects (Buildoffsite, 2012).

[8] Combines manufacturing techniques in factories and on construction sites with an open system for products and components
[9] http://www.williampoole.com/factory_built/

3. Offsite sector profile

- The most recent estimates put the value of offsite construction at £1.537 billion.
- Potential for growth within the offsite construction sector has been identified notably as a result of drivers in relation to the need for higher volume output in home building and the impetus of the low carbon agenda. Offsite is also an opportunity to build quicker, more efficiently and respond to government targets.
- Factors such as national/regional differences and related local demand, availability of materials, access to finance, access to skills and training, foreign competition, and capacity to bring products to market impact on the ability of the sector to achieve critical mass.
- The economic climate, impact of the energy efficiency agenda and market demand will strongly dictate the pace of change in relation to a shift to offsite construction.
- Currently offsite accounts for a relatively small volume of construction output, and anticipating short, medium and long term skills needs and on what scale is extremely challenging.

3.1 Size and value of the offsite construction sector

Whilst not within the scope of this research to quantify the scale and value of the offsite sector, it is useful to consider its profile and how this may have an impact on the scale of skills and training needs.

However the literature review found that there is relatively little systematic information on the size and profile of the offsite sector as estimating its scale and value is extremely challenging, in part due to the difficulties in defining a constantly evolving sector which has overlaps with manufacturing.

The first attempt to quantify the offsite construction sector was undertaken by Loughborough University in 2004, and estimated that the value of the sector was around £2.2 billion (Vernikos *et al.,* 2012).

The most comprehensive overview of the UK industry was undertaken in 2006 by MTech for Buildoffsite. It concluded that, in that year, the total value of the ‘innovative offsite’ sector – defined specifically as that part of the industry using techniques not as yet routinely used in mainstream construction – was around £1.5 billion, and that the offsite sector as a whole could be worth as much £6 billion. It identified 346 companies in the sector of which 60 were importers, although for many companies offsite was a relatively small part of their total turnover (Buildoffsite, 2006).

At this point, the two dominant components of the innovative offsite sector were permanent volumetric units and timber framed superstructure, (i.e. the part of the building extending above a given baseline, usually the above ground part that would rise above the foundation) representing 28 per cent and 26 per cent of total value of innovative offsite respectively. Although the report noted that this was not wholly representative, as a considerable part of the value of the volumetric producers was accounted for by fit-out of the modules and contract works, which usually takes place onsite. Some way behind were bathroom pods and re-locatable volumetric units, each accounting for around 9 per cent of the sector. Pre-cast concrete (6 per cent) and light steel superstructures (4 per cent) were smaller still.

The report did not, however, seek to analyse the maturity of the offsite industry, meaning that it is difficult to assess the relative profiles of the innovative and mature sections of the sector. It is possible, for example, that pre-cast concrete and light steel (which are widely used techniques in ‘mainstream’ construction) represent larger proportions of the overall offsite sector than of innovative offsite.

Respondents to the depth interviews in this study displayed uncertainty regarding the extent to which MMC more generally, and offsite methods in particular, are currently taken up by the industry – one estimate put the take up of MMC at around 10 per cent of the industry building offsite in any major way.

This is partly because of different perceptions as to the definition of offsite. As one ‘innovator’ who is heavily involved in research into MMC stated “*there is a difficulty pinning down people’s perceptions of what offsite might mean. Every building company will use some form of offsite construction*”.

Another interview respondent to this research noted “*things become traditional once they have been in operation for a while, even if they are technically classed as MMC*” – for example thin joint masonry is viewed as a legitimate form of MMC, as is the manufacture of roof trusses, but these are not necessarily ‘new’ technologies.

3.2 Potential for future growth of the offsite construction sector

A recent estimate has suggested that the offsite sector contributed £731 million of value added in 1998, a figure which increased to a peak of £2.08 billion in 2007 before declining to £1.537 billion in 2008 (Gambin *et al.,* 2012).

The Callcutt Review predicted in its 2007 report a potential for offsite construction to increase market share substantially by 2016, as indicated in the table below, which also draws on calculations by MTech (Callcutt, 2007).[10]

Table 1: Estimated potential for offsite construction to increase by 2016

Offsite system	2005 output	Proportion of UK total 2005	Proportion of UK total 2016*
Timber frame – all types	42,000	18.6%	30%
Light steel frame (LSF)	8,800	3.9%	25%
Precast concrete panel (cross wall)	<4,000	<1.5%	High growth predicted
Structural insulated panel	600	0.3%	4%
Volumetric modular	2,000	0.7%	4%
Hybrid (pod and panel)	300	0.15%	No data

*Data researched as part of a joint study undertaken by Association of British Insurers and MTech Group

Table and source data taken from The Callcutt Review, p. 30, which cites MTech data.

3.2.1 Quality and safety

An increase in offsite could precipitate a reduction in onsite accidents (such as falls from height) and generally improve many aspects of health and safety. This is partly because offsite can reduce the need for working at height, and also because there are likely to be fewer personnel onsite, thus reducing the extent of risk.

Within factory environments health and safety is typically easier to control, enabling consistency in quality standards to be tightly monitored and achieved. Damage from onsite storage is also reduced.

[10] The terms of reference for the Callcutt Review included an examination of “how the supply of new homes is influenced by the nature and structure of the house building industry, its business models and its supply chain, including land, materials and skills”, and “to consider how these factors influence the delivery of new homes to achieve the Government’s target (200,000 new homes per annum), meeting house buyers’ requirements and aspirations, achieving high standards of energy efficiency and sustainability as set out in the Code for Sustainable Homes, and progressing to a zero carbon standard”.

However it should also be noted that different methods of working, for example a greater use of plant and lifting equipment, could prompt an increase in other, or even introduce new, risks. CITB recognises a potential for revised safety training to address this change, for example heavy lifting and more mechanised equipment (CITB/Experian, 2008).

3.2.2 Time and cost reduction

Offsite enables the prefabrication of components within factories working under controlled conditions. This means timescales can be more rigidly controlled and completion dates predicted with accuracy, as offsite assembly is not constrained by changes in the weather or restrictions to access onsite. This in turn can equate to better productivity and greater efficiency once the components are transferred onsite, as there are fewer risk factors that could affect overall timescales.

3.2.3 Offsite methods for home building

Recent literature discusses the extension of offsite methods to home building, most notably in the 2013 *Offsite Housing Review* by CIC. Offsite has been an area of growing importance to the housing sector and in particular appears to have been a growth area in residential construction. In January 2004, a Housing Forum report estimated that 17,000 houses a year were being built with offsite methods and, in 2006, Space4 reported that it sold 3,000 panelised pre-fabricated houses, representing 2 per cent of all houses built that year.[11]

Given the shortfall of approximately 3,000,000 homes in the UK and the consequently large potential market for new housing starts, there is also considerable potential to drive the uptake of MMC and offsite in particular to enable developers to increase production beyond current limits (Menendez *et al,.* 2012).

3.2.4 The energy efficiency and low carbon agenda

Richard Ogden, chair of Buildoffsite, believes that offsite is *"on the cusp of a step change"* with the catalyst being the carbon agenda (Davis Langdon, 2011).

The current environmental context means that the high efficiency and reduced waste of offsite manufacturing are considered particularly advantageous. This is especially because of the ease with which offsite can be combined with advanced techniques such as BIM (Davis Langdon, 2011).

[11] 'Spot the Problem with Modern Methods of Construction', (7 March 2006) http://www.building.co.uk/spot-the-problem-with-modern-methods-of-construction/3063721. Article accessed 27/06/2013. The report quotes 30,000 houses, but this must be erroneous as it would represent around 20 per cent of housing construction.

The Government has announced a requirement for all new homes to be carbon neutral from 2016 onwards (HM Treasury, 2011). In order to support this, Part L (Conservation of Fuel and Power) of the Building Regulations is being revised to require greatly enhanced thermal performance in new and refurbished properties.[12] The CIC's offsite homes panel considers this will, if fully implemented, act as a major driver for offsite construction, due to the difficulties of consistently maintaining the build quality needed to attain the standard consistently using only onsite production (CIC, 2013).

3.3 Risk factors for the offsite sector

3.3.1 Typical SME business models

Companies operating in offsite construction tend to specialise in a particular construction process, or a material, or both - for example, timber, steel or concrete; modular/complete buildings, or non-volumetric pre-assembly.

The industry seems to be divided between a small number of major producers and a larger number of smaller firms. Firms operating in the offsite field vary on a spectrum of large-scale production, predominately home builders and firms specialising in commercial structures, operating out of regionally based 'hubs' (i.e. where the components are built) to micro companies focusing on a niche product.

These smaller companies appear to typically evolve around a particular technology, or product, with innovation at their core.

This business model appears to work as both a facilitator and as an impediment. On the one hand it introduces into the market new ideas and products; on the other hand shifting the balance in favour of innovation may mean that commerciality can suffer. A difficulty in raising finance for new products is a key challenge. Indeed, in recent years, as a result of these pressures, a small number of independent SMEs operating in the offsite market have ceased trading.

There are examples of some small companies which have achieved success through growth by sub-contracting with larger companies, collaborating with academics and academic institutions, or a combination of both. Some larger, main contractors have entered the market or extended their market presence through acquisition, such as Yorkon Ltd (part of Portakabin) and SES Prism (part of Shephard Group).

[12] http://www.planningportal.gov.uk/buildingregulations/approveddocuments/partl/ accessed 19/06/2013. Note: devolved nations have their own building regulations

This research has found, however, that many existing SME sub-contractors (who account for the largest share of the existing construction industry) are not involved in offsite activity. There is a sense that some 'traditional' builders, for example, view the advancement of offsite construction as a threat to their business, or are reluctant to adopt this approach. For instance, one interviewee, from a major industry federation, suggested these companies generally have limited knowledge of MMC.

Findings from other depth interviews suggest there is some sector variation at a granular level. It has been suggested, for example, that the uptake of research (i.e. bringing new knowledge or technologies to market) in the area of closed panel systems is fairly short, with 'quick' lead in times. This is tempered, however, by difficulties in collaboration and challenges in obtaining Intellectual Property rights.

3.3.2 Bringing products to market

It has long been recognised that the UK does not always manage to commercialise the technologies and innovations developed by researchers in an effective way. In particular, the Construction Industrial Strategy notes that the construction industry exhibits 'low levels of innovation' and notes that *"investment in R&D and intangible assets such as new processes (particularly in the contracting sub-sector) is low due to uncertain demand for new goods and limited collaboration"*. It notes other obstacles to realising the sector's potential for growth and modernisation, including:

- **Skills:** substantial fall in apprenticeship completions in construction related sectors relative to other sectors. Low training among self-employed and skills shortages among trade and professional occupations inhibiting technology deployment and innovation.

- **High degree of fragmentation:** relative to other sectors and countries which impacts on levels of collaboration, innovation and ability to access foreign markets (HM Government, 2013).

The implication appears to be that there is a very strong advanced research base, but relatively little direct connection between this research base and industry activity. This finding was confirmed through roundtable discussions (most notably in Scotland), which suggest the cause to be attributable to both parties: industry must see a business benefit to such collaboration; academia must be willing to share research and work in partnership on particular projects.

The growth of offsite, in short, is not simply a matter of bringing advanced technologies to market, but developing a research and development infrastructure and associated skills base that is far more directly focused on commercial and industrial applications.

For instance, the actual component technologies of cross-laminated timber (CLT), finger-jointed lengths of timber, polyurethane cements and hydraulic presses, are simple. For this reason, it is questionable whether CLT is the kind of product that would normally receive research funding in the UK's highly competitive research environment, where the emphasis is on developing the most advanced materials and techniques.

In this context, some respondents to this research emphasised the need for dependable technologies, and the gulf between the research programmes of the major universities and what was practicable or realistic for individual enterprises to manufacture.

3.3.3 The impact of the economic downturn

There is a general perception that offsite is growing in importance and will continue to do so in the future. This is clear from literature and from responses to the depth interviews, amongst all respondent groups. However, the prolonged period of economic slowdown has impacted disproportionately on construction, and offsite construction has suffered as a consequence.

There is a huge amount of opportunity posed by MMC but on the other hand companies are going bust all the time. They have to have an economically viable throughput to survive and this is difficult to achieve. The opportunity can only be realised if there is a boom

Innovator feedback, England

There are opportunities to use modular products but contractors decided against it because they feel that modular businesses are often closing down. It's the downside of lean manufacturing in a construction industry that is suffering due to the recession. There is also the problem that you have to pay a large cost upfront for modular construction and if the company closes then you have probably lost that money

Innovator feedback, Scotland

At the same time, however, it is possible that the tighter control of costs enabled by offsite might actually lead to expansion of the sector, particularly for large projects where standardisation of components makes economies of scale readily achievable.

Government investment can also play a part. In China, pre-fabrication has, in the past, been of poor quality resulting in some cases in building collapses. Quality of projects has improved more recently and is now considered to be guaranteed following the introduction of critical Government policies. The Construction Law has resulted in an improved supervisory system and higher prices being charged, and this is underpinned by technological innovations and better management, leading to fewer issues relating to quality.[13]

[13] http://www.construction-manager.co.uk/agenda/cm-learns-way-dragon/ accessed 19/06/2013.

3.3.4 Overseas competition

There is a key issue of potential competition from foreign construction contractors. The USA is the leader in pre-fabricated housing, representing in 2008 some 26 per cent of the global market (CIC, 2013). Around 20-25 per cent of US homes are offsite manufactured (Na, 2007). The supply of customised houses has also been developed in Germany by WeberHaus and Huff Haus, and in Japan by Toyota Housing. In 2004, offsite manufacturing accounted for one in every seven new houses built in Japan, with companies such as Sekisui homes producing around 150,000 pre-manufactured houses per year (Smith, 2008). The Japanese are currently expanding export of offsite housing products into Australia and other markets (CIC, 2013). The Chinese are now making extensive use of pre-fabricated, offsite methods, with one developer completing a fifteen storey building in only thirty days.[14]

A Polish property developer, BUMA, has developed a steel frame modular product for the UK market, which is manufactured in its Krakow factory. The unit is delivered onsite and bolted into place, and is only marginally more costly than traditional in situ apartment construction.[15]

The self-build market is currently a small one in the UK but which has a significant presence of foreign importers such as German manufacturer Huf Haus and Svenskhomes which offers homes manufactured in Sweden. The situation is confirmed by interview respondents who have cited examples of Swedish, Austrian and German companies leading the field in the manufacture of fully-serviced panels complete with pre-cut pipes, electrics and plumbing.

It also appears that certain parts of the sector are dominated by largely imported products, such as Structural Insulated Panels, where it was estimated in 2006 that 80 per cent of the market was imported (Buildoffsite, 2006).

3.4 National differences and geographic 'hubs'

The available literature contains little additional information on the regional profile of offsite construction, or supporting figures on the size of local markets, although there is recognition that the offsite sector has considerable potential; for example in Scotland, offsite construction, along with low carbon activities including zero carbon homes and retrofit "*present an enormous opportunity for the industry, including the opportunity to export*" (Construction Scotland, 2012).

[14] http://www.construction-manager.co.uk/agenda/cm-learns-way-dragon/ accessed 19/06/2013 .
[15] http://www.cnplus.co.uk/news/homes-with-all-modular-cons/394016.article accessed 19/06/2013.
http://www.building.co.uk/data/cost-model-offsite-manufacture/3042466.article accessed 19/06/2013.

Data on the situation in Northern Ireland is limited. One paper has estimated that as much as 50 per cent of all housing completions in Ireland currently employ offsite construction methods "*a large portion of which use timber framed construction as its primary construction method*" (Dublin Institute of Technology, 2008).The Northern Ireland Executive recognises the potential of modern methods of construction (including offsite) to "*provide considerable opportunities to reduce carbon input, achieve faster construction and reduce waste.*"[16]

Although not cited specifically in Welsh Government key priorities for the construction industry, offsite could make a contribution to those concerning monitoring and evaluating "*evolving market trends and offering evidence based and business focused advice relating to the skills agenda*" as well as improving "*the UK/overseas market penetration potential of competitive/niche high value businesses via market awareness/international trade programmes.*"[17]

Some regional differences in the adoption of offsite have been reported by interviewees for the study, with the distribution of offsite construction activity felt to be fairly uneven. Generally, offsite construction is described as largely concentrated in the South of England, however certain *types* of offsite are reported as being prevalent in certain regions e.g. timber framing is reported as being more widespread in Scotland and Wales than in England. This suggests an associated variation in skills and occupational profiles at a regional level.

There is some sense among a small number of users contributing to this research that national differences exist. Scotland has been manufacturing and building with prefabricated timber frames since the 1970s and some interviewees estimate that around 70 per cent of new build domestic properties in Scotland are now built using this method: predominantly open frame systems. It has been suggested by respondents that this is due in part to the weather conditions across Scotland, which make it desirable to produce a structure that is weather proof at an early stage in construction, and then have the electrics, plastering and decorative jobs carried out in weatherproof conditions. These 'interior' jobs can be completed to a higher standard than where the workforce operates on a traditional site open to the elements.

[16] http://www.northernireland.gov.uk/index/media-centre/news-departments/news-dfp/news-dfp-september-2008/news-dfp-250908-dodds-backs-northern.htm

[17] http://wales.gov.uk/topics/businessandeconomy/sectors/construction/keypriorities/;jsessionid=B5AD19D77FB325ED446458448CD5A268?lang=en

Respondents suggest that the North of England continues to favour ‘traditional’ construction methods and that, whilst the industry in the South has demonstrated some reluctance to change, on the whole, it is more accepting of offsite construction methodologies; more so for infrastructure projects, commercial buildings, schools, hospitals and student accommodation than perhaps large scale domestic builds.

4. Skills for MMC and offsite construction

- Core skills, knowledge and behaviours for offsite construction that are needed particularly by higher level occupations include:

  - mutual understanding, knowledge of other roles and collaborative working;

  - marketing and business case development;

  - project management;

  - information technology, i.e. BIM skills and knowledge of CAD and automated tools;

  - planning and design;

  - a whole life approach i.e. consideration of the whole lifecycle from cradle to grave.

- There is a clear need for more collaborative working, requiring so-called ‘softer’ skills such as problem-solving, team-working and communications. However it is not just about skills needs; knowledge needs also increase, for example in relation to the importance of accuracy and precision, greater awareness and understanding of other job roles and how they need to work together within offsite construction.

- This suggests that ‘behavioural development’ is as important as skills development.

- In considering skills and knowledge needs, the overlap between the construction and manufacturing sectors are also pertinent, due to a shift towards offsite assembly of manufactured components rather than ‘traditional’ construction. Although one school of thought suggests that this equates to de-skilling, the majority of respondents to this research argue that this points to a need to adapt the existing skills base, requiring multi-skilling and up-skilling, given the need for greater precision and potentially higher standards of quality.

During the height of the last construction boom in the years before the financial crisis, it was often suggested that skills shortages, especially shortages of electricians, joiners and bricklayers, would drive the uptake of MMC and offsite (BRE, 2002). There is some evidence from depth interviews of contractors introducing offsite walling elements to compensate for a shortage of skilled construction workers, especially bricklayers (Cole and Stevens, 2006).

A shift towards a more technologically focused method of working in any industry (such as those associated with 'high value' or 'added value' work processes) equates to a more demanding knowledge base. A key change to the current skills profile over the medium to longer term will be at a higher level. 'Trade' skills are arguably less likely to be affected; however the situation in which those skills are applied would change from an onsite situation to an offsite factory base in which conditions and processes are more tightly controlled. The manufacturing environment will still employ the traditional trade skills, such as carpentry and joinery for example, but in a more controlled environment.

> *Concentrating skills in factories nurtures the interaction that makes centres of excellence. Products can be tested before they reach site. The results can develop into loops of information which feed back to the manufacturers, creating a culture of continuous improvement. This also makes it easier to target specific weaknesses where research efforts might be directed, making R&D spending efficient and effective.*[18]

This emphasises the importance of collaborative working and sharing of information.

There is debate, in the literature and among participants in this research, concerning the capacity of offsite to reduce the skills demands made by the construction process, through improved efficiency and greater automation. At the same time, however, any sustained expansion of offsite in response to labour shortages or skills needs will generate increased demand for skills from the manufacturers, suggesting that to some extent skills issues may be displaced rather than resolved (Buildoffsite, 2012).

In 2006, the Barker 33 report concluded that shortages of skills were the main barrier to uptake of MMC and offsite methods, and according to the group's chair, Dr Ashley Lane, *"The issue is not about the product… It's about skills: logistics and planning and project management, training labour, education."* [19] [20]

Existing research has identified a number of specific areas where skills development and integration will be necessary if offsite is to grow substantially:

- Assembly skills for carpenters and joiners assembling timber-framed buildings, as they must be assembled to appropriate tolerances and standards if they are to achieve their designed level of structural integrity and thermal performance (Dublin Institute of Technology, 2008).

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[18] http://www.cartwrightpickard.com/ethos/offsite.aspx Quote taken from website

[19] Barker 33 Cross-Industry Group (2004) Modern Methods of Construction; An examination of the barriers to the greater use of modern methods of construction in the provision of new housing and the mechanisms to overcome them

[20] Spot the Problem with Modern Methods of Construction', 7 March 2006 http://www.building.co.uk/spot-the-problem-with-modern-methods-of-construction/3063721.article accessed 27/06/2013.

- Plumbers and electricians working on timber structures will need to be aware of how to cut holes and channels for services without compromising the building's structural integrity and thermal efficiency (Dublin Institute of Technology, 2008).

- Managers and supervisors will need the skills to integrate offsite products and components with onsite processes (CITB, 2011).

- Architects will need to coordinate a collaborative design process and help to envisage products for a manufacturing process, as well as know how to integrate them into a design. This is expected to re-skill rather than de-skill architects.[21]

Functionally, although the skill is unchanged, the application and context of offsite construction is likely to require a more productive and effective method of working in order to achieve process efficiencies. This equates, essentially, to a heightened appreciation of accuracy and consideration of other trades and the whole build process, for example an appreciation of the design process and engineering disciplines (CITB/Experian, 2008). Rather than skills development this could be considered 'behavioural development'.

By extension therefore, managerial skills and knowledge will need to be developed; respondents to the depth interviews almost unanimously recognise the imperative for extended knowledge at a high level, particularly in terms of the managerial function.

> *MMC will lead to increased automation which could lead in turn to a substantial reduction in bricklayers, plasterers, tillers, plumbers, etc., onsite. Initially these skills will be needed offsite but in time it is likely the skill level will be reduced due to factory methods and conditions – with one skilled supervisor overseeing lower skilled operators* (ConstructionSkills, 2010).

As the build process in offsite become increasingly integrated with manufacturing functions, process management therefore becomes progressively more critical. A broad base of skills will be required, bringing together oversight of both offsite and onsite activities, these include for example:

- site safety;

- risk management;

- quality control;

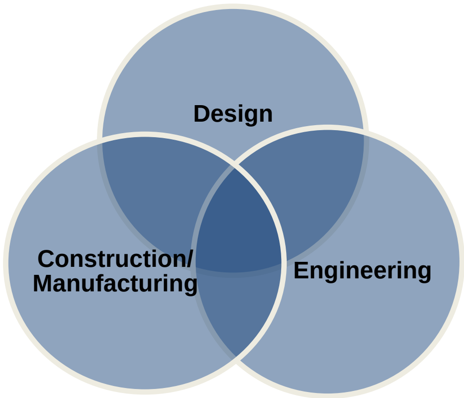
- sequencing.

[21] http://www.cartwrightpickard.com/ethos/offsite.aspx

Over time and, depending on the level of adoption of 'lean manufacturing' principles, the oversight function will become increasingly reliant on technology to automate and control the build process.[22]

In the longer term, as offsite construction becomes increasingly integrated with manufacturing, a more sophisticated process will emerge, likely heavily reliant on technology and necessitating a managerial profile based largely on scientific and technical skills.

Figure 2: Ideal mix of 'front-loaded' skills offsite



Respondents to the depth interviews collectively described a situation which calls for an equal balance between managerial and technical capability. Managers will need to manage a greater number of variables and diverse teams, bringing together seamlessly the offsite and onsite work functions.

Sites are increasingly becoming areas of assembly: this requires different disciplines to work very closely together. Important elements are timing, sequencing and precision, underpinned by speed and quality. These can only be successfully achieved through effective team working and communications:

> *For professional services MMC will require integration of construction processes from design through to construction and maintenance, implying a need for cross-disciplinary education for design teams. Also there will be a need for more CAD-trained design technicians working offsite* (ConstructionSkills, 2010).

[22] 'Lean' principles are essentially those aimed at increasing market share, whilst minimising the resources used – an approach generally accepted as being pioneered in Japan.

The main barriers to skills integration are currently seen by respondents to this research to be a lack of knowledge by sub-contractors within the traditional wet trades, which account for the bulk of the industry. This manifests most commonly as what is perceived to be resistance to change by traditional builders, and a perception that offsite is much more attractive and appealing to larger employers.

4.1 Skills, knowledge and behaviour needs for offsite

Figure 3 below summarises the mix of skills, knowledge and behaviours required for MMC and offsite. The summary has been developed from an analysis of the depth interviews, round table discussions and literature review.

Whilst most skills are related to high level disciplines (such as management level grades and equivalent), some craft related skills are also considered important for offsite construction.

Figure 3: Skills, knowledge and behaviours needed for MMC and offsite construction

Skills

- Project management
- Planning and design
- Onsite placement and assembly skills (greater degree of tolerance)
- Logistics
- Maintenance and repair of offsite components
- Computer-Aided Design (CAD)
- 3D drawing
- Carpentry
- Joinery
- Risk management
- Quality control
- Management of diverse teams
- Customer service and interaction
- Air tightness
- Process improvement
- Supply chain management
- Whole life costing
- BIM modelling
- Procurement
- Just In Time systems
- Site preparation
- Information technology
- Operation of machinery

Knowledge

- Situational awareness i.e. knowledge of other job roles
- Integration of offsite products and components with onsite processes and materials
- Cross-disciplinary education
- Promotion and business case development of offsite
- Minimisation/avoidance of waste
- Time and sequencing allocations
- Handling and storage of offsite products and components
- Site safety
- Health & safety principles and legislation
- Lean manufacturing principles
- Design and assembly costs
- Impacts of ‘getting it wrong’ (assembly onsite)
- Materials and components composition – applications and properties
- System performance
- Sustainability – processes and materials
- Negotiating and influencing

Behaviours

- Flexibility/adaptability
- Communications
- Collaboration and team-working
- Problem solving
- Accuracy and precision
- Speed and efficiency
- Consideration and awareness of other roles

Core skills, knowledge and behaviours, particularly for higher level occupations, identified by interview respondents and roundtable delegates are listed below. These are discussed in more detail in the following sections.

- knowledge, mutual understanding and collaboration;
- marketing and business case development;
- project management;
- information technology;
- planning and design;
- a whole life approach.

4.1.1 Knowledge, mutual understanding and collaboration

The depth interviews and roundtable discussions (particularly responses from 'users' of new technologies) suggest a greater focus on a 'knowledge economy', or an effective utilisation of knowledge, in future, rather than a substantial shift in the skills profile of the workforce. Knowledge-based collaboration is also cited as a future skill in the literature (Echert and Kazi, 2007).

A need for better 'situational awareness' i.e. a clearer understanding of other job roles and the overall project, as well as behaviours such as risk scanning and effective communication, and inter-disciplinary education, have been frequently cited in interviews and each roundtable discussion as priority needs for the offsite workforce. In particular these are identified as priority needs for the site supervisor/project manager. Key aspects of this awareness and understanding are identified as needing to span:

- knowledge of all the remits undertaken by the different trades operating offsite and onsite;
- precise tolerances and accuracy plus the need for high quality standards required for onsite assembly, and the implications of getting it wrong;
- the impact of logistical issues, including working effectively within time and sequencing allocations, and how to deal with problems;
- understanding how to minimise or avoid waste;

- an understanding of how different materials and components interact onsite, including how to handle, move and store them.

At a supervisory and site management level, this equates to an understanding of material and component composition, their applications and properties and the importance of precision. An understanding of the importance of placement and assembly is also likely to necessitate a working knowledge of both design and rudimentary engineering principles.

Site supervisors and labourers will require an understanding of modern terminology, as well as an ability to comprehend and follow instructions on new materials and components. Site workers will need a greater understanding of general building issues such as tolerances, air/water-tightness, and how components interact (CITB/Experian, 2008).

For professional services, MMC will mean an integration of construction processes from design through to construction and maintenance, pointing to a need for cross-disciplinary education for design teams.

The potential of high level skills is pertinent here in terms of collaboration, as a means of contributing to one of the UK Governments 'joint commitments', to:

> *Identify global trade opportunities for UK professional services, contracting and product manufacturing, developing partnerships and promote UK construction through the GREAT brand* (BIS, 2013).

Greater knowledge of how different job roles, such as electricians, plumbers and carpenters, interact with one another will also be required, however respondents do not anticipate significant changes to the technical skills needed of these types of occupation.

4.1.2 Marketing and business case development

There is a need to be able to articulate to potential home-owners and investors the benefits of offsite construction methods. This requires well-honed business skills in negotiation and influencing to promote, market and sell the concept, as well as the technical skills and understanding to deal with customer questions.

> *Manufacturers are not very good at promoting their wares, levels of sophistication, promoting their messages and marketing themselves, potentially producing products without actually thinking about what the market actually wants*

Stakeholder feedback, UK Government

Offsite construction, and its associated technologies, needs to be sold on two levels:

- to the finance sector in terms of investments into offsite projects, mortgages and insurance;
- and to the public to create demand.

> *We had to go right to the top and get in front of a Board Director and then we still had to re-sell the product into every region because they are all run as though they are separate businesses. Once they saw how well the product worked – i.e. how quickly it could be used – the volume orders came in but we really had to prove ourselves first.*
>
> ***Developer feedback, West Midlands***

Historically, there have been significant problems with non-traditional construction in the UK, with the failure of some types of post-war pre-fabricated housing systems, particularly in concrete system-built structures. The 1984 Housing Defects Legislation identified a series of post-war concrete systems that were prone to unacceptable deterioration.[23] There has also been evidence of failure in early steel system built houses (BRE, 2002).

Such problems are to some degree intrinsic to any innovative techniques, where it is possible that unanticipated problems may emerge either because of design flaws or, perhaps more likely, due to an insufficiency of skills and experience in implementing new building methods.

The design lifespan of modular construction is currently around 60 years, and this can be contrasted unfavourably with the seemingly limitless design life of well-executed masonry construction.

The result is that mortgage lenders and financial institutions remain cautious about providing finance for non-traditional methods of construction, which can be viewed as untested, potentially prone to major failure, and difficult for surveyors to assess reliably.[24] Such issues may have significant impacts on the availability of mortgages to potential private domestic clients, and also to developers looking to secure finance for larger developments.

[23] http://www.cml.org.uk/cml/policy/issues/107 accessed 02/09/2013
[24] http://www.cml.org.uk/cml/policy/issues/107 accessed 02/09/2013

Progress has been made in this area, however, by collaboration between the Council of Mortgage Lenders (CML) and the Building Research Establishment (BRE), to develop a new certification standard for MMC – LPS 2020. According to the CML the standard is *"intended to meet the concerns of lenders, insurers and other stakeholders in terms of key issues such as durability, whole life costs, reparability, insurability and flood resilience"*[25,26]

Markets for offsite include civil and industrial structures as well as housebuilding. As previously stated, there is reluctance within some parts of the industry as well as among consumers to embrace offsite; this highlights the importance of having people with marketing skills and robust case studies that can help to 'sell' the concept and underpin business development. This must also be backed up by testing and promotion of new technologies to underpin business growth and volume output for builders.

If research and development is industry-led or developed, this can be an advantage that can help bring a product to market more quickly.

> *It helps if there is a client on board – we can get to market quicker if they recognise the risks*

Innovator feedback, England

Other obstacles can also prevent or delay technologies being brought to market. For example the implementation of innovative timber offsite MMC techniques is necessarily limited because there is no Eurocode compliant software platform for the sector (Menendez *et al*., 2012). Regulatory issues including health and safety considerations are a necessary consideration but can also lead to delays or negative associations where issues have occurred.

Conversely safety requirements could be a positive driver of change. A high percentage of site deaths occur at height, and removing the need for scaffolding (not always able to support prefabricated structures hence hydraulic platforms must be used instead) could be a major influencer of change. Similarly if scaffolding does not have to be in place for as long, given the shorter length of time onsite, this would reduce health and safety risks to the workforce.

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[25] http://www.cml.org.uk/cml/policy/issues/107 accessed 02/09/2013

[26] It is worth noting that it is the individual property, rather than a design or a set of components that constitutes security for a loan. Reparability and adaptability are also key criteria for insurers when making finance decisions on a property

There are also cultural issues, with a perception that many customers are suspicious of offsite because of negative associations with post-war ‘pre-fab’ housing, and *“resist any innovations in house construction which affect what a “traditional” house looks like*” (Goodier and Gibb, 2005).

> *The greatest barrier is public perception. The house buying public want traditionally built homes. There has been no great change in the way that houses look and are laid out in over 100 years (with just a few notable exceptions). Modern technologies are often used to dress up pre-fabricated elements of buildings to make them look traditional*
>
> ***Innovator feedback, England***

The ability to pass on knowledge to the customer/homeowner will also be important for the future.

Literature suggests that customer service and ‘specifying’ skills may increase in importance as the consumer is given greater control. Off-the-shelf designs are predicted to increase as offsite technology is integrated further into the housebuilding market, in future requiring a more customer-centric design and configuration process, possibly enabling customers to choose and specify their home online.

This is significant because of the associated ‘inflexibility’ of the design process; decisions need to be made early in the design process, that are not easy to adapt or change once production has begun.

For example customers are likely to be able to order modular homes online, and also personally play a part in designing and customising their homes using interactive design websites or a ‘kit of parts’. This approach has been in practice in Japan (Toyota Homes) for several years, whilst in the UK, customers are able to specify their design online, add optional details and receive a guideline price. [27] [28]

> *The evolution of the construction industry, including shifts to offsite manufacture, ties in with the concept of Open Building Manufacturing. This concept places the customer at the heart of the construction process, strives for a more efficient industry encourages collaboration and is value and knowledge-driven* (Alshawi *et al.,* 2007).

4.1.3 Project management

[27] www.toyotahome.co.jp
[28] Companies offering this service include Rapyd Rooms www.rapyd.co.uk and Ecospace www.ecospacestudios.com

Project management skills in their widest sense were recognised by a large number of interview respondents, most notably amongst 'users', as being critical for the future development of offsite construction. The integration of manufacture (offsite) and assembly (onsite) were most frequently cited in terms of contributing to the need for skills in overseeing the entire construction process.

A range of skill sets are noted as important within the project management function, such as supply chain management and balancing the timing and sequencing requirements of a 'Just In Time' approach[29]. This also requires associated skills in logistics (e.g. planning routes) and placement. Scheduling is a critical sub-set of the project management skills base.

These sets of project management skills are viewed as becoming more important over time, with operational management skills combining with technical skills and knowledge.

> *Offsite makes it more important to consider how work is planned, designed and scheduled. If managers have qualified with high level current qualifications but their expertise is traditionally onsite then it could be very difficult to move to offsite. It's not necessarily the technical skills that are different but more the softer skills including planning, sequencing and link between design and build.*
>
> ***User feedback, Scotland***

Effective management of both processes and people are viewed as essential.

- The **process factors** include; procurement; supply chain management, whole life costing, health and safety, design management, lean construction, sustainability, tolerance and quality.

- The **people factors** include: communication, role of the project manager, culture, client/design team, leadership, perception and integration (McCarney and Gibb, 2012).

The ability to identify and embed process improvements will be informed by the integration of project information, therefore comprehensive knowledge and understanding of BIM is also considered vital (see below).

4.1.4 Information technology

[29] An approach, originally pioneered in Japan, to improve efficiency in the manufacturing process. Essentially, the process eliminates the need to hold surplus stock of products or components, resulting in savings and reducing waste.

The use of BIM will be mandatory for all government projects by 2016, therefore, by association, increasing the importance of effective IT skills required to use the technology.

Interview respondents foresee increased emphasis on IT skills and general capabilities in the application of new technologies, the prime example being BIM.

There is a widespread consensus among respondents that BIM is having, and will continue to have, a “great effect” on the industry: in particular upon the design, scheduling, management and quality of offsite construction projects. Clients can be shown designs in 3D (in some cases 4D) and are able to take a virtual tour of the build/manufacturing process and the projected end result. A number of interview respondents highlighted the future importance of BIM to the project management process; some see this as a panacea for the challenges identified, but this technology is of course not unique to offsite construction, nor is it infallible.[30]

In addition, therefore, skills are needed to undertake detailed and accurate 3D drawings in order for offsite to operate effectively (i.e. designs and concepts need to be correct first time).

> *The really sad thing is that BIM offers manufacturing on a plate to the industry and they just don’t get it. It offers standardisation and creativity opportunities. The key is to standardise the things that should never be creative and allow more time and opportunity to be creative in other areas of building.*
>
> ***Innovator feedback, England***

More automated production processes will also need to be underpinned by effective IT.

As a comparison, in engineering consultancy, people are required to maintain a strong working knowledge of software developments, but traditionally the construction workforce does not have this same level of on-going knowledge of IT systems and how to best utilise them as they evolve.

This is certainly true of craft and trade roles (for which the skill requirement is arguably limited) but is also highlighted in the literature as a concern for high level roles: *“skills gaps at a high level have been identified, including those in engineering, management and ICT and in SMEs”* (Gambin *et al.,* 2012).

[30] The benefits of developments in BIM modelling are not exclusive to offsite construction, but are equally important and usable in regard to traditional construction, and therefore to class BIM as a technological advancement ‘within’ offsite construction is perhaps to ignore a wider circumstance.

4.1.5 Planning and design

The take-up of offsite construction processes presents a number of challenges to the construction design and planning stages, with opinion divided as to whether this introduces greater design freedom or supresses adaptation.

The process of offsite manufacture has been described by many respondents to this research as akin to the automotive manufacturing process. The comparison is that the finished product is most often signed off in its entirety before manufacture begins and that the manufacture itself is a repetitive ‘conveyor belt’ type process. Within traditional construction it is not common to commit to the solution so early in the process. There is usually some flexibility and this is valued by architects, builders and end users/purchasers alike.

The integration of design and planning will require skills to deal with different phases of building, including: development; production; utilisation and disposal. Such stages are commonly associated with a product lifecycle and integrated into modern manufacturing processes, such as the ‘Design for X’ concept outlining an ideal approach to improving life-cycle cost and quality, for example (see section 4.1.6 for further detail).

Adopting such a concept would, for the construction industry, require regular interaction between designers, engineers, architects and the project manager.

> *Designing for manufacture is a skill that we need to work on – it’s a mix really of a traditional design architect and a consulting engineer role. It’s all about turning what was a construction process into a manufacturing process.*
>
> ***User feedback, UK-wide***

> *There are issues in terms of how design links with construction. A builder or installer responds to specifications but if the design isn’t quite right then there is a problem. On that basis the designers need to understand some of the technical detail and vice versa.*
>
> ***User feedback, Scotland***

The literature review found a perception among architects and designers that offsite and, in particular, modular construction therefore restricts design freedom. There is a belief that complex customised shapes cannot readily be accommodated in the offsite model, and that traditional onsite methods are more flexible (Cole and Stevens, 2006). The design must also be 'frozen' at an early stage, meaning that ad hoc improvements or modifications cannot be made once the manufacturing process begins, although from some designers' perspectives this can be considered an advantage (Jenny Hayes/O'Connell East Architects, 2009).

One of the most significant impediments has been recognised as the inherent inflexibility of housing system design components, which are difficult to exchange or adapt, therefore limiting customisation (Abosaod *et al.,* date unknown). This is it odds however with other findings which suggest the opposite: that offsite offers a highly flexible and customisable option (Echert and Kazi, 2007).

It is possible that developments in BIM will make this less of a problem, since this is making it easier to predict many aspects of the functioning and performance of a building at the design stage; for example, through 3D modelling and 'testing': an important consideration for the housing market, particularly in terms of 'customisation'.

In addition, it is worth noting the following disadvantages identified by the architects working on a major building project that was constructed using offsite modular components (Jenny Hayes/O'Connell East Architects, 2009):

- lack of adaptability of finished structure (volumes of modules are unalterable);
- modules are limited in size due to transport limitations (physical and regulatory);
- cost efficiency often requires quantity e.g. cost of using large cranes to move around large pre-fabricated components and modules.

Some of these issues are much the same as those identified in recent research with contractors in the USA (transportation issues, limited design choices and the inability to modify the scheme onsite) suggesting that they are likely to be robust and enduring issues (Na, 2007).

4.1.6 A whole life approach

Design principles that embrace the 'whole life approach' are likely to apply increasingly to construction if it continues to move forward into more mainstream adoption of offsite technologies; these are accepted in facilities management disciplines for example, and are becoming more prevalent in terms of product sustainability in manufacturing.

There may also be a need to change procurement and project management practices. Full volumetric approaches should ideally be decided upon before the design process begins, whereas the usual procurement process designs first and then seeks tenders for construction (design, bid, build); the usual 'critical path' based project management approach assumes a largely sequential approach to construction, whereas offsite enables simultaneous completion of different parts of the construction process (Modular Building Institute, 2012).

> *For a building system to be considered truly sustainable from an environmental perspective, the whole lifecycle from cradle to grave must be taken into account including embodied energy of the raw materials, the transportation, production and construction emissions, and the energy consumed during use and at the end of its life* (Sanna *et al.,* 2012).

Repair and maintenance will always require 'traditional' skills but knowledge will need to be expanded.

According to Goodier et al, "*prefabricated houses might never be actually repaired or renovated onsite"* (Goodier *et al.,* 2012). The depth interviews have confirmed that the accepted life-span of many modular structures is generally acknowledged to be no more than 60 years, designed to be removed and replaced rather than refurbished or modernised.

This could have an associated impact on trades specialising in repair and maintenance: a market dominated by SMEs. However the volume of traditional, existing building stock in need of on-going repair and maintenance should soften the impact of this potential decline.

Greater integration between builders/trades and manufacturers in terms of repair and maintenance will vary as each system is currently slightly different. The bespoke nature of the offsite industry means there is limited cross-fertilisation between different systems. The result is that manufacturers will need in future to work closely with repair and maintenance disciplines to maintain the original design features of the structure.

This is a critical factor when considered against the potential contribution of the offsite market to the sustainability and low-carbon agenda. Essentially repair and maintenance professionals will need to be highly skilled to maintain air-tightness for example, and will need to understand (as do specifiers) the importance of using the correct materials and components, and fitting them to the required tolerances. In some cases it may be desirable or indeed necessary to replace individual pods or sub-structures in order to maintain a building's environmental credentials as integrity may be compromised by the alternative.

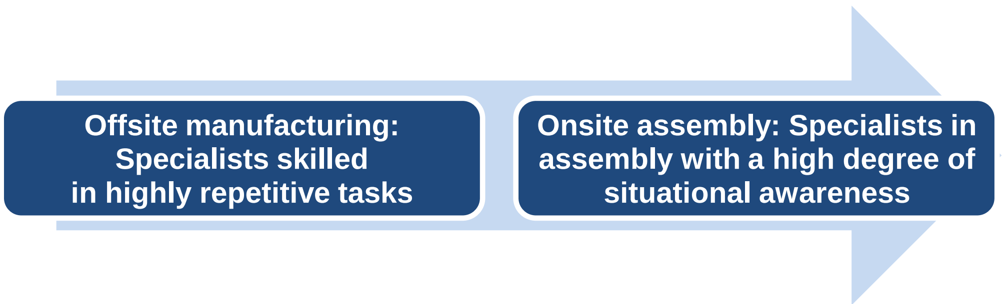
Manufacturers are expected to be in the best position to advise on the repair and maintenance of the building and offer documents and manuals to the building owners on the 'whole life' management of the building.

For offsite, maintenance is typically simpler; buildings are delivered with an accurate plan of where wires, pipes, etc., are in walls and under floors so it is easier to access them for servicing or avoid them when altering.

4.2 The impact on the skills supply chain

A key function for the future will be subsequent onsite 'assembly' of offsite manufactured components, rather than 'construction' in the traditional sense (Balfour Beatty, 2012).

Figure 4: Core skills differences between offsite manufacturing and onsite assembly



This will have a knock-on effect on building services engineering disciplines and, primarily, mechanical and electrical trades. These trades will still be needed, but likely not for as long during the construction process in future, as the onsite finishing period will be much shorter, curtailed by factory automation. Other traditional onsite skills will not change, such as undertaking the drainage and foundation work as part of site preparation.

In this scenario the installation process would be conducted in a piecemeal fashion on a production-line type basis, supervised and quality assured by a qualified overseer.

[There will be] greater mechanisation and automation onsite. Much of this can be achieved by wider use of existing tools and techniques (craneage etc.) but it will have implications for new skills or a wider need for skills in craneage and lifting, for handling large loads and logistics onsite etc (CITB/Experian, 2008).

Respondents are not suggesting that dedicated occupations and expert roles will disappear altogether as a result of offsite construction, however there will be a need for greater flexibility and multi-skilling so that individuals can adapt their existing skills base to work with a wider range of materials and projects. This points, overall, to a 're-skilling' rather than 'de-skilling' scenario.

Many commentators and contributors to this research suggest that a broader skillset will become a requirement as offsite becomes more typical. However there is a sense that the result may be a more stark separation between offsite and onsite skills and job roles but with a common 'generic' skills base. Others have gone on to suggest that if the discrete build systems and processes are taken up by the industry in greater numbers there is a sense that system-specific skills will be in demand.

Onsite skills needs will be more about installation than construction, this does not necessarily represent de-skilling but is more about flexibility and adaptation. Workers may in fact need to be more highly skilled because the level of quality and tolerances are more tightly defined. Standards of workmanship might be expected to be higher.

What there is probably a need for are multi-skilled people that are able to understand the interaction between different materials, for example if you put timber and insulation products together, that will require knowledge of factors such as condensation risk. It is less about the individual materials but more about how they interact.

Developer feedback, UK-based (International operations)

A lot of precision onsite equals more skilled people onsite. Exactly the opposite of de-skilling.

Innovator feedback, England

Contrary to most beliefs, offsite calls for very high skills levels. It is precise and strategy led so everyone has to understand how their role works within the whole process.

User feedback, UK-wide

5. Occupations and job roles

- This research has identified a need for core, or primary occupations within offsite construction, supported by other secondary and tertiary job roles. In this context:

  - primary occupations are necessary for both design and delivery of offsite projects;
  - secondary job roles will contribute to delivery, such as component assembly;
  - tertiary roles will have a more supportive function, for example office administration.

- As offsite currently accounts for a relatively small proportion of the construction sector, impacts on occupations to date have been limited. Over the longer-term, should offsite be more widely embraced and adopted, certain occupations (such as architects and designers) could be expected to evolve, requiring different and broader types of skills and knowledge, as well as potential overlap between managerial and professional roles.

- A critical occupational mix for offsite is that of design, engineering and project management. A typical staffing model for offsite companies tends to employ such roles on a permanent basis, whilst additional employees in other roles may then be recruited on a short-term basis, often through agencies.

- Few ‘brand new’ occupations are expected to emerge as a result of offsite, however certain roles will increase in importance, such as site supervisors/project managers, designers, architects and engineers. However certain essential roles can be in short supply when it comes to having the skills and knowledge needed for offsite, notably design engineers, structural engineers and architects.

- Impacts on lower level ‘trade’ occupations are less likely in the short to medium-term. Whilst the number of lower level job roles could be expected to reduce onsite, this is likely to be offset by an on-going need for repair and maintenance of existing building stock, meaning that traditional job roles such as electricians, plasterers, carpenters and so on, are unlikely to be substantially displaced by a need for semi-skilled labour in offsite factories. The latter may also open up opportunities for more entry-level jobs.

5.1 Job roles in offsite

The characteristics of MMC and offsite construction dictate a need for ‘core’ or primary job roles in addition to others at secondary and tertiary levels. Primary job roles are essential for both design and delivery of offsite projects, whilst secondary job roles are required to contribute to delivery, for example by assembly offsite or onsite. Tertiary roles carry out a supporting or indirect function, for example through scheduling of component delivery in a logistics role, procuring the right types of materials or by supplying finance for the project (Figure 5).

All three types of role require knowledge of the offsite process, albeit to different extents, with primary roles inevitably needing the most comprehensive knowledge base most critically in terms of ‘cross-disciplinary’ understanding of roles at both primary, secondary and tertiary level, combined with a commitment to collaborative working.

Figure 5: Primary, secondary and tertiary job roles required for offsite construction

Primary

- Architect
- Planner
- Site Supervisor
- Project Manager
- Designer
- BIM Modeller
- CAD Specialist
- Supply Chain Manager
- Structural Engineer
- Consultant
- Logistics Manager
- Technician
- Quantity Surveyor
- Technical Salesperson
- Manufacturer

Secondary

- Plumber
- Electrician
- Carpenter/Joiner
- Bricklayer
- Roofer
- Plasterer
- Painter/Decorator
- Insulation Installer
- Heating, Ventilation, Air-Conditioning & Refrigeration Engineer
- Welder
- Masonry Worker
- Glazer
- Tiler
- Factory Worker

Tertiary

- General Labourer
- Design Office Administrator
- Scheduler
- Procurer
- Banker
- Insurer

5.2 Demand for job roles for offsite

Evidence from the roundtable events and depth interviews suggest recruitment companies specialising in sourcing workforces for offsite construction projects find common recruitment needs are:

- schedulers;
- site labourers;
- project managers;
- quantity surveyors;
- design office staff including BIM modellers;
- engineers.

CAD specialists and quantity surveyors can also be in high demand.

It appears to be fairly common for specialist offsite companies to be ‘front loaded’ with skills, with research respondents alluding to organisations consisting of a small number (relative to the size of business) of permanent, highly qualified professional staff including a Design Manager, Structural Engineers, Project Manager and so forth, with the remaining staff brought in (typically from agencies) on short term contracts. Thus there is a clear need for a mix of roles spanning design, engineering and construction/manufacturing to underpin effective offsite work.

There is a slight shift away from reliance on architects at design stage to design modellers. The need to commit to an end product at an earlier stage in the design and build process, can “sit uncomfortably” with architects, who are said, by respondents to this research, to prefer to maintain a greater degree of flexibility to change throughout the process.

The requirement for design engineers will continue over the short to medium term, with developers predicting that over the medium to long term additional roles in site and process operations management will increase in demand.

One ‘user’ of new technologies (a large civil engineering contracting firm) suggested that IT specialists with engineering knowledge are currently in demand. If the offsite market continues to grow and, depending on the rate of growth, it is likely this demand will increase in the short term. Literature broadly supporting this finding suggests that more CAD-trained design technicians will need to work offsite (ConstructionSkills, 2010).

5.3 Supply of offsite roles

Respondents, in particular 'developers' of new technologies, report difficulties in recruiting designers and architects that have the full spectrum of skills and knowledge needed for offsite. Typically these people have to be trained up via an 'in-house' bespoke training course, or sent abroad to countries such as Belgium or Austria, where training provision is considered fit for purpose, unlike the UK alternative.

> *There are not enough design engineers – we have been trying to recruit them for months. Because the right skills are not available in the market place the next best thing is to find people with the right drive and train them up.*

Developer feedback, UK-wide

Organisations are looking for people that can work collaboratively, but such people can be in short supply, making it difficult to form and nurture 'long-term' teams.

5.4 The impact of offsite on job roles

5.4.1 Evolution of job roles

Offsite is still a developing part of the construction industry and so, to date, changes to job roles have been somewhat limited from a national perspective. More wide-reaching changes are predicted by interview respondents to occur over the course of the next 10-15 years, but, critically, only if the use of offsite increases.

On the whole respondents believe offsite will have a stronger impact on certain job roles, whereby they will evolve to require different types of skills and knowledge. For example a need for multi-skilling and greater flexibility within job roles is likely to feature for onsite assembly, requiring dedicated tradespeople to be able to undertake more than just one task, such as electricians that can also carry out basic plastering.

Offsite could thus result in multi-skilling becoming more 'mainstream', with smaller teams being required to assemble components onsite, needing to work more closely together. One example cited during interviews was the building of a 90 room student hall of residence in 4 weeks with only 6 people needed to work onsite. In this context, priority onsite skills would therefore relate to assembly and installation.

> *Offsite needs only 4 or 6 people to finish a building onsite, and they tend to work in a cooperative way. The workload is more clearly defined, and holdups eliminated*

Developer feedback, UK-wide

As set out in section four, people in specific occupations will also be expected to work more collaboratively rather than in silos and this will require a clearer knowledge and understanding of other job roles and how they contribute to the holistic offsite project. For example, BIM operates on the crucial premise of ‘design for manufacture’ therefore architects, or perhaps in future architectural technicians and design engineers, must be involved very early in the process as there is less scope for on-going modifications in the offsite process.

For offsite, more information is needed at an earlier stage in the design process, as well as consideration of the fact that work will be predominantly undertaken in a manufacturing, rather than a construction environment, which must be factored into the roles undertaken by architects and structural engineers.

5.4.2 Existing priority roles

Whilst a range of job roles are affected by offsite as outlined in Figure 5, respondents have identified the following occupations as being 1) the most important to and 2) the most affected by offsite:

- site supervisor/manager or project manager;
- designer;
- architect;
- structural engineer;
- planner;
- BIM modeller.

Site Supervisor/Project Manager

The person in charge of the site is effectively the lynchpin of the offsite operation, and needs to possess an extremely broad skillset relating not just to technical skills, but also to business and project management, as well as effective communications, problem-solving, team-working, supply chain management, logistics and an understanding of Just in Time systems. Situational awareness is an important behaviour.

Designer/Architect/Planner/Structural Engineer

Perhaps more than ever before, those operating in design and planning roles will need to have a broad knowledge base spanning aspects such as energy efficiency, precise degrees of tolerance onsite, design and assembly costs, how materials and components interact with each other and system performance. Additionally, skills in CAD and the ability to work with high degrees of precision and accuracy will be vital.

BIM Modeller

This role is expected to become increasingly important over time, and requires not just the technical modelling skills, but also knowledge of the design role and process management.

Technical salesperson

Another role that is expected to evolve is that of the salesperson, with a need for a more technical sales role as a result of changes to the way customers might purchase in the future.

The technical salesperson therefore needs to possess a comprehensive knowledge base in relation to the range of different technologies and systems that could be used in the home, how the materials interact with each other, how they will perform over time, how energy efficient they are, and how the customer needs to behave in the home to maximise the benefits. Additionally, skills will be needed in effective communication and customer interaction.

Procurement Manager

The role of the procurement manager will also evolve in relation to offsite, with a need to procure construction works in a different way. This will require an understanding of the whole life of the building, rather than the typical approach being to just procure work or materials for the roof, walls or floor for example. Furthermore offsite offers time-specific benefits that can reduce costs and ultimately increase the value to the client which would need to be taken into consideration at procurement stage.

5.4.3 Hybrid roles

Respondents have identified a clear need for the supply chain to work together in a more integrated and collaborative way.

This may result in overlap of roles particularly at managerial and professional levels, for example the remit of a design manager crossing over with that of the commercial and facilities managers notably because of the additional work required at site preparation stage. However regulations or Health and Safety Legislation can sometimes prevent too much overlap between disciplines.

> *In general more crossover between roles is occurring at every level.*

User feedback, UK-wide

> *There has to be integration between design, manufacturing and construction and procurement roles.*

User feedback, UK-wide

Integration of teams is an important factor; whilst this may not create specific hybrid job roles as such, it will create a working environment whereby different job roles have a better understanding of what their colleagues are required to do, and in some cases will be able to undertake some of their tasks. Integration means that the supply chain can be procured at an early stage of the process, thereby bringing expertise in while the design of the building is taking place, enabling all parts of the supply chain to input and add value to the project. This in turn can bring about cost savings to ultimately benefit the bottom line and the client.

To some extent there is crossover between the traditional role of the consultant, and that of the architect. A shift away from the traditional design process, whereby an architect designs a building and the builder constructs it, means there are now more specialist consultants working in architectural technology often focusing upon low carbon and environmental concerns. Where previously architects may have carried out this remit themselves, changes to buildings and materials have necessitated more specialist functions.

5.4.4 New roles

> *Offsite does not present a radical change (in terms of emergence of new occupations) – it is more about adapting to meet the changes.*

User feedback, England

Few job roles that could be termed ‘brand new’ are expected to emerge as a result of MMC and offsite, however certain roles are expected to become increasingly important, such as logistics managers, site/project managers, and design engineers. The latter appears to be in particularly short supply, with some organisations struggling to recruit the skilled and experienced design engineers that are needed.

> *It is not really about new job roles, as it’s merely a transfer of skills from onsite to offsite. This will require people with a very good understanding of how systems are put together onsite.*
>
> ***Developer feedback, UK-wide***

Trades may therefore adapt, as there will be different inspection and testing requirements, which could also impact on the traditional remit of designers and engineers (CITB/Experian, 2008).

The energy efficiency agenda may be a key driver for new job roles in the future, as more technologies are developed, and existing technologies improve and are adopted more widely.

Within the factory offsite environment there will be an increased requirement for factory skilled workers, whereby certain tasks can be carried out by semi-skilled workers. In the depth interviews the example was given by an ‘innovator’ of a prefabrication company that set up their business in Daventry specifically as they knew the location would provide a good source of semi-skilled labourers with manufacturing experience.

5.5 The impact on lower level occupations

As described in section four, the expectation is that the skills of existing onsite trades will not necessarily be substantially affected by an increase in onsite manufacturing and production, however the environment and context in which those skills are applied may well change. This is predicted by respondents to the depth interviews to be a gradual transition, rather than an immediate shift. There is some debate as to the impact that a growth in offsite will have on the numbers of workers required onsite in future.

Mass production in a factory setting can be easier to control, and requires a different type of skillset than that needed on sites. Certain trades would be negatively affected by a higher degree of factory pre-fabrication, such as roof cutting, and there remains a concern among industry reported in literature and in 'users' interviews in particular that 'old' trades (typically at lower levels such as bricklayers and joiners) could be noticeably reduced. This is of particular concern to these trades where there is a trend towards technicians assembling pre-fabricated components onsite, rather than traditional tradespeople.

The main impact is expected to be a reduction of the number of these lower level job roles that are needed onsite; however this does not necessarily mean that traditional skills and trades would no longer be required, as it appears (at present) extremely unlikely that offsite will entirely displace traditional construction methods.

Furthermore there is still expected to be a need for lower level job roles in offsite factories, at least in the short-term. Over the longer-term automated methods may develop and if widely adopted, may require operators that are less skilled, which would pose a risk to traditional trades (although it should be noted that offsite currently accounts for a small percentage of construction output) but opens up opportunities for entry level job creation (CITB/Experian, 2008).

This may not have a significant impact on the actual numbers of workers required however:

> *The processes of construction may be more automated – but there are still people managing and operating the machines so the greatest change is the movement of labour rather than its loss.*

Stakeholder feedback, UK-wide

> *Offsite construction carried out in factories can employ many thousands of people who would otherwise be out of work. It opens up a new labour market.*

Developer feedback, UK-wide

> *Increasing use of offsite will lead to more manufacturing based jobs but will to some extent displace a need for significantly greater number of low-skilled jobs in traditional construction.* (CIC, 2013)

There could also be fewer opportunities for repair and maintenance tradespeople, as some pre-fabricated products are not expected to require as much maintenance as traditionally built structures.

There is already the issue of an ageing workforce across the traditional trades; if these skills are lost then it would appear this would be a more significant concern for traditional construction rather than offsite. Offsite manufacture can operate with large numbers of semi-skilled labourers within factories, although highly skilled individuals would still be needed at design stage, and ultimately onsite to oversee and carry out assembly.

> *Traditional jobs will change and be deskilled. Electricians, for example will not need to be as skilled because the skill will be required in testing and commissioning work, not in actually carrying out. The majority of the workforce will be semi-skilled labour carrying out repetitive jobs.*
>
> ***User feedback, UK-wide***

> *There is a huge increase in the manufacture of plasterboard and dry-lining. On a production line you don't have to be a qualified and skilled tradesman to carry out these tasks.*
>
> ***User feedback, Wales***

5.5.1 Entry routes and the skills pipeline

A number of respondents have suggested that the offsite factory environment could be more appealing to young people who may have been put off a career in construction by the perception of the 'dirty' site working environment. It has also been suggested by one stakeholder respondent that this method of working could also open up career pathways to long-term unemployed people through the creation of entry level jobs with lower level skills needs.

Both of these scenarios present an opportunity to respond to the issues of skills undersupply and recruitment.

6. Qualifications and Training

- There are concerns among respondents to this research that offsite construction does not feature strongly enough within existing training provision. Isolated ‘pockets’ of specialist courses tend to be the norm, rather than nationwide coverage.

- Similarly, current qualifications are perceived as being too narrow, and there is a risk that a disconnect between industry needs and academia could have a negative impact on the design of any new qualifications and training courses.

- The gaps in existing provision typically mean that offsite companies are largely compelled to design bespoke in-house training, or else consider sending their employees abroad to train, or even recruiting people from other countries where training and qualifications are deemed far more fit for purpose.

- Notable gaps relate to:

  - apprenticeship frameworks (focus on traditional methods as opposed to offsite);

  - offsite project management;

  - accuracy in hand 3D drawing (rather than simply relying on computer software)

  - BIM;

  - design technologies and materials used in offsite.

- Over the longer-term, these issues could mean that the UK lags behind its international competitors.

6.1 Perceptions of existing training and qualification provision

At present it appears that most training for offsite construction takes place in-house. On the whole, respondents feel that changes need to be made to existing training provision in order for it to be sufficiently fit for purpose in relation to offsite.

Particular issues are around training in discipline silos, rather than interdisciplinary, enabling development of multiple skills; a disconnect between industry needs and training providers; and a perception among many employers that they must create their own bespoke, in-house training because of gaps that exist in external training provision.

A strong concern is that offsite construction does not, typically, feature strongly within existing training provision, with only limited time given to teaching relevant techniques and knowledge. This can have knock-on effects over time leading to skills shortages within the industry, exacerbated by an ageing workforce and limited numbers of new entrants to the sector.

> *The 'training machine' is geared towards bricklayers and re-engineering that for offsite could be a challenge*
>
> ***Stakeholder feedback, UK Government***

Furthermore, current qualifications are perceived to be too narrow, with heavy concentration on homes and traditional construction and therefore insufficient coverage of offsite construction. A key concern is that existing qualifications tend to be standalone, whereas respondents have identified a need to embed greater understanding of cross over and integration between roles and responsibilities. For example, whilst BIM features in a number of programmes, respondents feel that there is scope for much greater coverage than at present. Furthermore, the roundtable discussions conducted for this research highlighted the importance of designers and technicians being properly trained in the use of powerful and complex design technologies.

So-called 'traditional' approaches of delivering construction qualifications, particularly craft qualifications, are perceived to be less relevant to offsite construction and MMC. This poses a risk if offsite is not afforded sufficient consideration moving forward, particularly among those organisations with a remit for education and skills, such as the sector skills council for construction, CITB.

Training in the UK can also be delivered via CPD courses to 'top up' gaps within FE and HE qualifications. However there is still a strong sense, as suggested by one 'innovator', that *"the (UK) education system is following rather than leading."*

> *Businesses are developing their own, better solutions (than are offered by many training providers) to deliver training that is bespoke to their needs*
>
> ***Innovator feedback***

6.1.1 Disconnection between industry and academic education

Responses to the depth interviews suggest an underlying issue is a disconnection between industry needs and the development of new academic programmes.

This appears to be substantiated by examination of the education and training provided by the key research centres. At the moment there appears to be virtually no focused training at higher levels available for MMC or offsite methods. Indeed, it appears that attempts in 2009 to establish MSc and CPD courses in Advanced Manufacturing in Construction have not proved sustainable in the current education and training marketplace. Instead, the main focus appears to be on:

- very high level taught and research courses, such as the professional Doctorate in Engineering (D.Eng/EngD) with pure research-based degrees (PhD) that include a focus on MCC and construction technologies.

- consideration of new technologies, especially BIM, within the main professional degree programmes (Bachelors and Masters level) in civil engineering, architecture, architectural technology and surveying.

There also appears to be some provision of CPD, usually on a bespoke or one-off basis. Further examples of existing provision are provided in Appendix C.

6.1.2 Fragmented provision

Whilst there are pockets of specialist training, for example that offered by manufacturers, there does not appear to be a consistent training offer UK-wide that addresses the skills and knowledge needs for offsite. This is linked to regional differences: there is greater use of timber frame construction in Scotland and Wales than in England and Northern Ireland, which is reflected in the availability of training in different nations.

Training provision can also be fragmented, with ‘pockets’ of expertise in certain regions but a lack of widespread, consistent availability of relevant courses.

Building regulations can act as a catalyst or as a hindrance to the development and implementation of innovative components and technologies. Furthermore they can vary in each of the four UK nations, meaning change could be adopted at different paces, which in turn impacts upon the availability of training and can result in fragmentation of the training offer.

6.1.3 Limited apprenticeship provision

As with other forms of existing training provision, the majority of Frameworks focus on ‘traditional’ construction methods at the expense of MMC and offsite.

This is expected to result in skills shortages over time as young people enter the industry without the full spectrum of skills and knowledge needed. This is a particular concern in light of the approach to training in other countries; for example in Scandinavia and Germany trainees start in a vocational environment before attending university, and are thus able to combine practical skills with academic knowledge. This may mean that the UK is at risk of lagging behind other European nations.

6.1.4 Time and economic pressures

The industry is increasingly lean, and employers are facing on-going pressure to release individuals to attend training. Linked to this is the location and style of existing training delivery; a more flexible approach would make it easier for up-skilling to take place outside of normal working hours. Coupled with time pressures are economic constraints, which can mean that employers cannot afford to train employees that they may not be able to sustain in the longer-term, and in turn, training providers cannot afford to maintain courses that are undersubscribed.

6.1.5 Limited understanding of offsite training needs

It is not always clear within the industry which types of specific skills and knowledge are necessary for MMC and offsite; not all employees would recognise where they have a training need, as one ‘developer’ suggested: *“lack of understanding about the huge variety of skills and methods that come under the offsite umbrella”.*

Furthermore, the highly specialist nature of many technologies and components used in offsite construction makes the development of consistent provision extremely challenging for education providers. Until technologies and methodologies become more mainstream this situation is unlikely to change.

> *The industry needs to be able to gain the benefits of mass production while tailoring solutions to particular needs.*

Innovator feedback, England

6.1.6 Resistance to change

Respondents identified a certain amount of ‘protectiveness’ in relation to more traditional construction, and in some cases, a reluctance to embrace change or acknowledge that offsite could offer positive benefits. In some cases emerging technologies are perceived to be high-risk as they are largely regarded as untried and tested, so it can be difficult to raise finance for projects. Training providers are unlikely to embed changes to existing courses unless they perceive there is a market demand within industry first of all.

6.2 Gaps in training and qualifications

Depth interview respondents and contributors to the round table discussions reported a general lack of coverage of offsite construction processes and techniques in existing programmes.

> *Generally there needs to be recognition in the curriculum that offsite exists, and at least an overview of what can be achieved with offsite construction. New entrants to the industry from industry are still not really aware of what offsite can do. University professional courses do not include enough about offsite.*

User feedback, UK-wide

The point is not limited to undergraduate and post-graduate programmes however, and is valid as a commentary on CPD programmes and short courses. The issue is related to the breadth and depth of training and qualifications provision which is viewed by some respondents, and in literature, as silo-based and too skewed towards discrete job roles.

Comments in existing literature support this particular viewpoint:

> *Construction professionals need to be re-trained to think differently in order to approach a project with a new mind-set, which synchronises processes and activities with the manufacturing and design team from a very early stage* (Goulding *et al.,* 2012).

> *Workers in the UK are generally not provided with an initial broad-based training after which they specialise. Instead, they are usually trained for just one role which consequently makes adapting and multi-skilling difficult, i.e. a key requirement for an increased uptake in offsite. These issues need to be addressed and overcome if a significant expansion in the market is to occur* (Goodier and Gibb, 2007).

In terms of subject specific knowledge, there is a degree of unease around a lack of what has been termed “thermal literacy” by some respondents i.e. a limited coverage within training provision around measuring energy performance and interpreting information relating to the results. Further concerns exist around a perceived lack of interaction between FE and HE.

Other deficiencies within existing provision have been identified from both the literature and depth interviews as:

- delivery of project management skills that incorporate widespread knowledge and understanding of the offsite process and the impacts upon other job roles, the need for effective communication and team-working, and a need for greater accuracy;
- an increased focus on accuracy and 3D drawings undertaken by hand, not just by computer;
- training for site supervisors and managers on logistics (CITB, 2008);
- a broader understanding of the range of design technologies and materials that can be used in offsite construction;
- an increased focus on BIM within training provision.

> *To safeguard the future, it will be important to raise awareness and support the training and integration of BIM across all segments of the market, providing support and encouragement to the self-builder, the small to medium size house builder, the largest private house-builders, Registered Social Landlords, Local Authorities and other client organisations*. (CIC, 2013)

6.3 Responding to the issues

Respondents identified a need for a dual approach to embed offsite processes and technologies into training for new sector entrants and up-skill the existing workforce for offsite.

Although views were to an extent divided over the de-skilling (or perhaps more appropriately titled ‘re-skilling’) versus multiskilling debate pertinent to ‘lower level’ or ‘trade’ skills, respondents were collectively of the opinion that the most significant challenge in the immediate to longer term was concerning skills at a higher level.

Indeed, research undertaken by CITB in 2008 identified immediate training needs for designers, manufacturers and site management teams, challenging the view that the future skills challenge would centre predominantly on site operatives and site installation trades (CITB, 2008).

Strategic stakeholder interviewees outlined the need for a shift towards training that is more appropriate for an industrialised approach to construction. It is anticipated by many respondents that such a tactic may potentially open up export opportunities.

This change is necessary for two reasons: firstly to take advantage of export opportunities before other countries do so (thus leaving the UK behind), and secondly in order to protect the construction market and the job roles therein. For example, according to literature and responses from 'user' interviews, there is currently no UK-based production of cross laminate timber panels, with Austria a dominant exporter of this technology (CITB, 2008).

The resulting commercial advantage gained by Austria means that imports from this source are still preferred in most markets. This is the case even in places such as Canada where there are abundant supplies of timber and a number of emerging manufacturers. A recent project was built from Austrian CLT panels because the manufacturer *'had more experience and "the product was vastly superior in finish,'" than Canadian competitors*" (Taylor and Wilson, 2013).[31]

The majority of respondents strongly emphasise the need for training to be developed in close collaboration with industry stakeholders, as is the case in a number of other countries including the Netherlands, Denmark and Belgium.

There is a general sense among respondents that a training system that provides a broad overview of the construction environment before starting to specialise, would be most suitable for offsite. There appears to be broader coverage of knowledge requirements in addition to skills within training course offered in other countries such as Australia. The University of Melbourne, an example cited by two 'innovators' contributing to this research, developed a broad undergraduate degree structure in 2008. Students can try out a range of different work streams prior to committing to the one in which they want to major. This enables students to move into construction after gaining knowledge and skills in relation to the wider built environment, such as architecture. There is also a specialised Masters course in construction management lasting two years and spanning seven specialities.

[31] http://www.workingforest.com/ottawa-store-snaps-together-use-cross-laminated-timber/

This type of approach enables an easier transition from role to role without the need for significant re-training, as well as a better, more holistic understanding of the entire offsite process and the different roles and remits involved in project delivery.

Another example cited was of an approach utilised in Germany, which teaches a mix of onsite and offsite skills and knowledge, followed by practical simulations, delivered by a training centre overseen by industry representatives.

Industry respondents are looking for training provision that gives a much broader coverage of MMC and offsite in particular. There are concerns that not all universities are engaged with offsite and that it can form only a limited part of the curriculum, if indeed it features at all: according to one strategic stakeholder interviewee *"all too often it's a half hour class in a qualification that takes years to complete".*

> *There is a need for highly skilled individuals such as engineers and designers, estimators and contracts managers and training provision doesn't meet these needs in the timber industry. Timber is completely missed at university level. It accounts for about one week in a three-year degree course.*

Developer feedback, UK-wide

> *Architects are not taught to design for manufacture. Degrees should include advanced modelling techniques.*

User feedback, UK-wide

> *Very few architects are trained for offsite so they automatically design for quality rather than 'buildability'. As such, "the art of the possible" is not known to them.*

Stakeholder feedback, UK-wide

It is strongly apparent that training provision needs to incorporate broader knowledge as well as skills, as outlined in section four. This would necessitate a balance between theoretical knowledge and practical skills. A number of large employers state that the structure (though not always the content) of apprenticeship frameworks can often offer a more effective means of ensuring such a balance, in comparison with the typical structure of HE programmes.

One solution could be to incorporate “bolt-ons” to existing provision, a mechanism currently used by the industry for up skilling and for additions of specialist subjects. However for the most part, respondents do not believe that this would provide either the extent of coverage required within individual courses, or ensure sufficient volumes of training courses UK-wide.

A small number of respondents have suggested there is a need for an MSc programme in offsite to be developed. There also appears to be a need for some form of education programme in relation to new technologies, so that benefits can be effectively ‘sold’ to industry stakeholders, investors and home-owners. Respondents are uncertain as to who should take responsibility for developing and delivering such a programme, but some suggested trade federations and professional bodies could play a role, alongside manufacturers which are most likely to take primary ownership for promoting their developing and existing technologies, products and components.

7. Summary

Offsite construction is not a new concept, with the essential principles and approach having been in operation for many hundreds of years. In recent years however it is continuing to evolve, underpinned by the development of new technologies and drivers such as the low carbon agenda. This opens up scope for new working practices and skillsets within the construction industry.

Currently, offsite construction is not widely adopted, with current (2013) market share of offsite projected in 2009 at 7 per cent of construction output (Gambin *et al.,* 2012).

Geographic uptake differs across the UK, for example there is very limited adoption of offsite in Northern Ireland compared with the other nations. Furthermore, different processes and technologies are in use depending on the location, for example there is a high concentration of offsite timber frame construction in Scotland. This in turn can dictate the capacity and skillset of the local workforce, as well as the availability of relevant training provision.

In spite of the benefits that can be realised through offsite construction, a number of dedicated organisations have ceased trading in recent years – partly because of the impact of the economic downturn, and partly because there is not yet widespread demand for offsite.

The value and size of the offsite sector has not been clearly quantified and there is no universal definition of offsite construction. It is also challenging to attempt to quantify the profile of the offsite sector as many aspects of it are in fact relevant to traditional construction. Furthermore, once any aspect has been adopted for a number of years there is a tendency to categorise it as a ‘traditional’, rather than a modern, method of construction. This ambiguity in relation to the market therefore presents a challenge in relation to estimating the supply needs of the workforce.

The potential for growth within offsite is dependent on a number of influencing factors and drivers including the economic climate, energy efficiency agenda and availability of investment (notably where emerging technologies are not yet fully tried and tested, resulting in wariness and extreme caution exercised when considering whether to release finance). This, in turn, dictates the impact in relation to skills needs; suitability of existing provision and the need to adapt or develop new training and qualifications; as well as the pace of change which is largely dictated by market demand.

Increasing the uptake and use of offsite construction can realise benefits for the construction industry including improved quality, time-savings and greater efficiency and productivity.

The task of promoting the benefits of offsite construction methods is twofold: raising awareness amongst consumers (and commissioners of construction works), and educating the sector itself. It is apparent from this research there exists a degree of resistance from the wider construction industry to adopt offsite processes.

The potential for offsite is however attractive, not least in terms of generating export sales (a market already dominated by Germany and Austria) and offering cost-effective solutions to addressing housing demand, most particularly in the form of social housing, and industrial applications where time-critical solutions are valued.

Government support for offsite construction could help to bolster confidence amongst the sector, recently given a boost in the Industry Strategy, Construction 2025, through a close association with BIM: championed by the current government.

If the offsite sector does experience substantial growth, which may be stimulated by Government policies such as increased use of BIM, this is likely to mean some crossover of the manufacturing workforce into the construction industry, which could plug skills shortages in construction but potentially result in displacement for the manufacturing sector. This is underpinned by a shift towards onsite assembly rather than ‘traditional’ construction and requires fewer people onsite. However this could open up opportunities for entry level job creation and also be a more appealing option to attract young people into the construction industry, as offsite manufacturing usually takes place in a factory environment, with regular working hours and no need to be on a site subject to changing weather conditions.

There would also be opportunities for export and the growth of the UK’s manufacturing base if the offsite sector were to expand. Together with the likely crossover of the workforce, this could mean a certain amount of overlap between the manufacturing and construction industry footprints having some impact, upon industry stakeholders, such as Sector Skills Councils.

As a result of offsite, multi-skilling and de-skilling are both likely to happen, to an extent but the notion of 'de-skilling' is perhaps more about operatives having a lack of autonomy in the construction process onsite, rather than a lack of skills. There may be displacement of traditional trades onsite, as the offsite factory environment setting is likely to require higher volumes of semi-skilled labour e.g. from a manufacturing workforce, rather than traditional trades in the same volumes. This does not mean that traditional skills and trades would no longer be required. Job roles onsite and skills at a lower level are unlikely to be substantially affected and it is the application of those skills that will change, i.e. the context and environment in which they are applied; as well as a need for a different knowledge base to be kept regularly updated.

The differentiation between offsite and onsite is predominantly in the area of higher level skills. Changes needed to the skills and knowledge profile of higher level occupations will predominantly affect the critical roles of designers, planners, architects, project managers, and structural engineers.

The role of the site supervisor or project manager has been identified to be one of the most important occupations for offsite, and this person requires a comprehensive mix of technical skills, operational management, knowledge base and 'situational awareness' i.e. understanding the ways in which roles link and work together such as logistics and the wider supply chain, not just trades onsite.

This 'situational awareness' becomes even more critical for offsite as this is underpinned by a closer integration of skills and job roles, and more collaborative approach rather than working in traditional silos as is currently the case.

Critical skills and knowledge needs for MMC and offsite include:

- IT skills, not only in the application of BIM for example, but in the application of technology to project management and sequencing;
- situational awareness and a mutual understanding between trades of their roles, as well as an understanding of new technologies and terminologies;
- customer service and interaction, including the ability to 'sell' the concept of offsite and educate consumers;
- risk scanning, team working, collaboration and communications all need to be effective to support closer interaction at all levels both on and offsite;

- problem solving ability to deal with issues quickly and effectively, as the benefits of reduced time and costs when carrying out onsite assembly can only be realised if work is undertaken to the agreed schedule;
- planning and design, which needs to be supported by a clear understanding of the technical process of onsite assembly and other influencing factors such as how materials and components interact, and how energy efficient products might be incorporated;
- promotion of offsite and business case development to enable marketing of the concept of offsite construction and overcome negative perceptions in order to raise investment and customer interest;
- greater accuracy and precision is necessary both offsite and onsite, to work effectively within narrower tolerances;
- onsite assembly skills must be fit for purpose, particularly as there are likely to be fewer people working onsite to tight schedules and timescales;
- project management, as discussed above;
- quality control and assurance underpinned by higher standards of workmanship.

Qualifications and training provision to deliver these skills and knowledge needs are not perceived to be fit for purpose, nor available on a wide enough scale UK-wide. Respondents consider that offsite is only very narrowly covered within existing qualifications, apprenticeship frameworks and higher level programmes in stark contrast to similar provision in other countries.

This means that the offsite workforce (at higher skills levels) is often trained in-house, with some organisations choosing to train employees abroad in countries such as Austria, Germany or Belgium, where industry-led training models are perceived to work more effectively than those in the UK.

This may mean the UK risks lagging behind, and therefore opportunities offered by offsite might not be realised if these issues are not addressed quickly.

8. Implications

The following implications for government and the sector are presented in order of priority. Overall, further research to quantify the size and value of offsite and forecast its future growth and market demand, whilst a challenging task, could help to inform future skills, training and qualification provision.

8.1 Closer collaborative relationships

Greater collaboration between industry and academia, notably in relation to influencing the design of training and qualifications, could enable these to become truly industry-led, a model frequently used successfully in other countries.

In the short-term, given it is unlikely that rapid change will occur within existing training provision (unless there is strong evidence of market demand), a more realistic option may be to explore the opportunity of developing regional centres of excellence, which could be underpinned by collaboration between FE and HE institutions to pool expertise.

Consideration could be given to creating an Offsite Skills Network bringing together academia, research institutes and industry with the purpose of sharing knowledge and establishing an interface between innovation and commercial application. This could serve to facilitate a continual dialogue between both supply and demand sides of the skills arena.

The potential cross over between manufacturing and construction within offsite is likely to require greater collaboration between organisations at a strategic level. For instance, the Construction Industry Training Board (CITB) and SEMTA could consider the potential implications of a greater synergy between manufacturing and construction in terms of the supply of labour market information and, critically, the impact on Levy paying organisations in the construction industry. In this sense the current definition of ‘construction’ could be reviewed.

Employers, academia and other sector stakeholders such as professional bodies could work more collaboratively to identify and exploit opportunities. This in turn could help to stimulate market demand and thus increase appetite for skills development and training. This could be achieved through an industrial partnership making use of UKCES funds such as the Employer Ownership of Skills Pilot.

Such an industrial partnership could then be charged with embedding the following recommendations for the industry. In pursuit of this it will be essential that appropriate policy levers are used where relevant, such as UKCES investment funds.

8.1.1 Stimulating demand

Trade Federations and Professional Bodies may wish to work collaboratively on programmes to educate investors, industry stakeholders and home-owners. There is an appetite and interest in technologies amongst consumers, apparent from the number of television programmes dedicated to showcasing the design and build process. The focus here however is usually on the self-build market and therefore beyond the reach of the average homeowner.

In this context, the development of positive case studies could help counteract any negative perceptions in relation to offsite and stimulate consumer demand.

Engagement with those in procurement roles could be considered with a view to educating procurement professionals to understand the differences in procuring offsite works, and how this might impact clients in terms of costs, value for money and quality assurance.

8.1.2 Training and qualifications

Embedding appropriate coverage of offsite within training provision and qualifications can play a role in improving understanding and awareness of its potential, enabling the supply chain to play a part in spreading the message.

A culture of ‘multi-skilling’ could be embedded at training stage. For instance, training could seek to equip students with a broader skills and knowledge base about offsite enabling application of these core skills and knowledge to different settings, materials and systems. This would potentially enable students to become more familiar with offsite, its potential, and what can be achieved, as well as overcoming the perception that they are only trained to do one thing.

Training and education providers could consider approaches to offsite training provision in Austria and Germany in particular to learn lessons and identify good practice which can be transferred to the UK.

8.1.3 Careers information

Careers information, advice and guidance to those seeking opportunities in the construction sector that includes consideration of offsite construction job roles could help offer clear pathways to higher level occupations as well as promoting offsite to a greater diversity of people, including young people. This is particularly important given the issues of the ageing workforce in the construction industry.

8.1.4 Continuing Professional Development

Continuing Professional Development (CPD) could be a potential solution to top up gaps in skills in the short time. The construction industry is more likely to be able to take advantage of CPD that can be delivered flexibly (for example via webinars outside of core working hours), and that is not cost prohibitive.

The focus of such programmes could centre on knowledge acquisition, in particular: developing an understanding of offsite technologies and materials; access to finance and funding for the use and integration of new technologies; developing a wider appreciation of the integration of construction, engineering and manufacturing in the offsite process.

Appendix A: Methodology

The aim of this study was to understand the requirements for higher level (and supporting) technical skills in offsite construction. The study was supported by a number of objectives:

1. Understand the existing and emerging technologies influencing the skills needs of the construction industry;

2. Identify and document existing intelligence on the current and future impact of technologies on the construction industry;

3. Establish the range of skills required to meet the demands of harnessing current and future technologies;

4. Understand the impact that future skills needs might have on the occupations involved and the relationships between them;

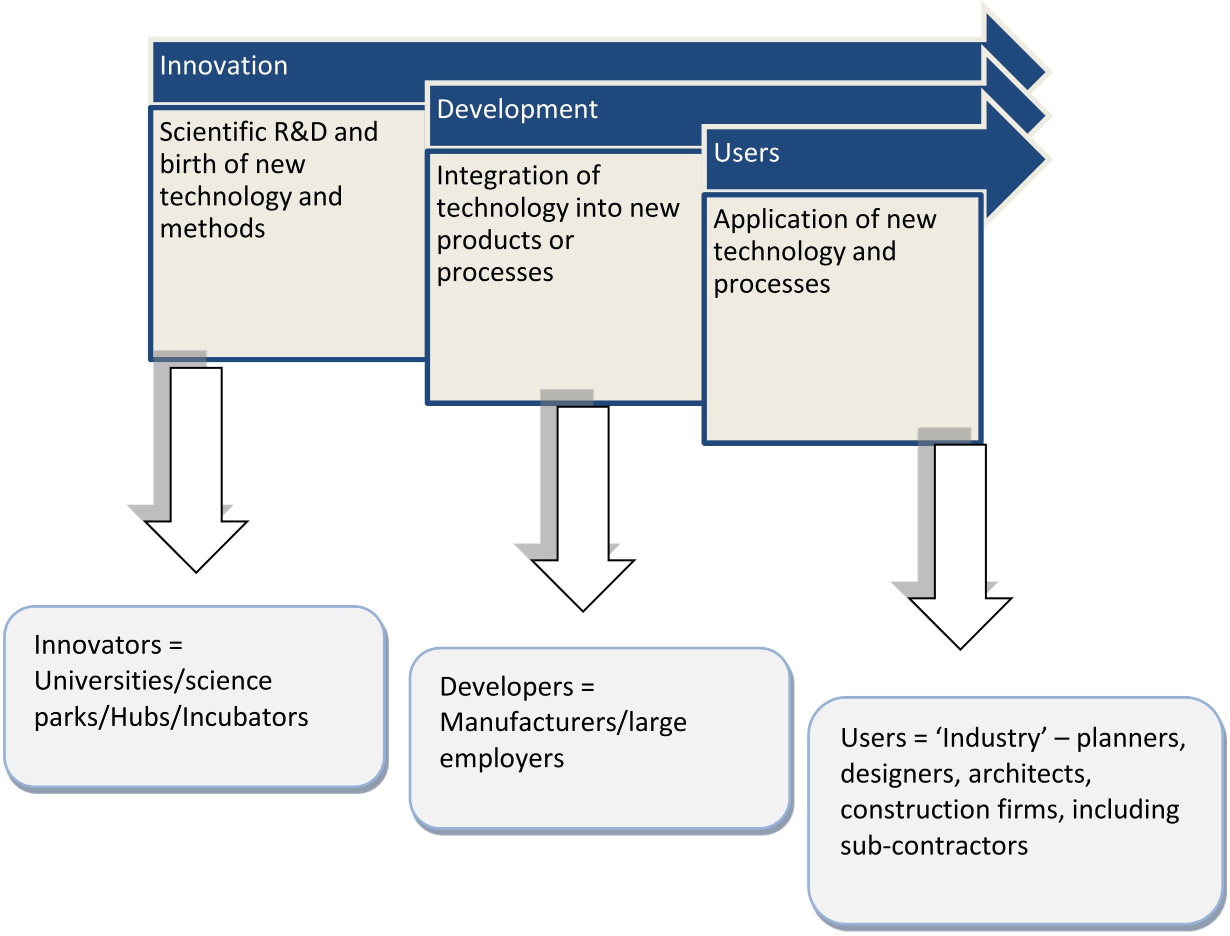
5. Establish the interdependencies between technology and other skills drivers such as regulation, competition and consumer demand;

6. Identify the opportunities and challenges posed by variations by nation, region and company size;

7. Understand the influence of technologies on the supply chain and how this chain may need to evolve;

8. Understand the opportunities and challenges for economic recovery and growth posed by the above in the short, medium and long term.

The approach to the research was based on a conceptual model focusing on the supply-chain of innovation. The investigation began with an examination of the ‘innovators’ of new technologies in offsite construction in particular, following to the manufacturers and developers of the technology, and onto the final end-users. This conceptual model is illustrated on the following page.



A mixed method approach was used which drew on the following activities:

- initial desk based scoping of sources and potential research participants ('innovators', 'developers' and 'users');
- secondary research, including a full literature review. This stage also drew on existing datasets such as those from the UK National Employer Skills Survey and the Employer Perspectives Survey;
- fifty depth interviews with innovators, developers and users;
- three roundtable events (England, Scotland and Wales).

Themes for investigation

The literature review and depth interviews were both conducted thematically, and concurrently from late February/early March until late May 2013. The following themes formed the basis for the research:

- policy – economic policies and skills policies that may serve to support or hinder the introduction of innovative methods;
- the technology – the potential contribution of offsite construction, its current take-up and predicted future trends;
- job roles – the impacts on current occupations, possible creation of new or hybrid roles, the impact on progression routes;
- skills needs – typical skills requirements, including both ‘core’ and ‘peripheral’;
- qualifications and training – existing qualifications, gaps, and the potential market for qualifications and training.

The roundtable events discussed the findings in further depth. Discussions were focused on the following topics:

Current job roles and higher level skills required

- the evolution of job roles – integration and diversification?
- skills requirements and progression;
- training and qualifications.

The future – what needs to happen?

- future economic potential;
- impacts on job roles and skills requirements (short, medium and long term).

Profile of research participants

Relevant individuals and organisations were invited to participate in both the depth interviews and round-table events.

Interview respondents were identified by the research team and contacted directly, interview respondents were also identified via recommendation.

The roundtable events were recruited from the depth interview and from publicity by industry bodies and UKCES.

Research participants were categorised into four broad groupings.

Interview participant category	Type of organisation
'Innovators'	University Academics (UK and international)
'Developers'	Manufacturers and producers of offsite technologies and components, and representative organisations of the offsite industry
Stakeholders	Government representatives and agencies
Users	Professional bodies and trade associations; local government; training boards; employer representative bodies

Appendix B: Technologies

Building Information Modelling (BIM)

BIM provides a vehicle for collaborative working which is what MMC hinges upon. The use of BIM will become mandatory for all Government projects from 2016.

The transition to BIM has a number of benefits. Design changes need to be entered only once and are then automatically included in all the drawings and specifications that are outputted from the model. In addition, rule based relationships between intelligent objects, known as 'parametrics', can also be established, meaning that when a building component is modified, some or all of the necessary associated changes can be made automatically in accordance with the rule. There are BIM software packages that can automatically detect clashes between building components or design errors – for example intersecting service ducts or structural elements protruding through finished surfaces.

Some BIM models can also incorporate timelines and building schedules ('4D BIM', where time is the 'fourth dimension') so that the design and construction processes can be fully integrated. BIM software can also be used to automatically calculate quantities and cost estimates (adding another dimension, cost, so creating '5D BIM'). In its most ambitious form, 5D BIM even allows the performance of the building to be modelled through its entire lifecycle, enabling accurate whole-life costs to be calculated for different design options.

This all has potentially wide-reaching implications for the adoption of offsite technologies. The design can be finalised more comprehensively and earlier, reducing or eliminating the need for *ad hoc* modifications during construction. When this becomes routine, the loss of flexibility traditionally regarded as a major issue with offsite methods is no longer such a problem. Moreover, the use of standardised formats and a single integrated modelling process enables much greater coordination of the programming, designing, specifying and construction processes.

This is again likely to facilitate the move to offsite methods, since it allows all the various parties involved, potentially including offsite manufacturers, to be actively involved in progressing the design and construction process, rather than requiring a series of discrete stages with 'handovers' between them. This means that designs can be optimised for offsite production with far greater ease than under a more traditional 'design, bid, build' construction model. Finally, by encouraging consideration of whole life costs, BIM is likely to highlight the superior performance characteristics of precision manufactured offsite building components.

Cross-laminate timber

Cross-laminated timber (known as CLT or XLam for short) is a recently developed system of panelised offsite construction. Originating in research by Swiss and Austrian scientists in the 1990s, it is an engineered timber product that applies the same basic structural principles as those used in familiar plywood products: it consists of sheets of wood built up in layers, with the grain direction running perpendicularly in each successive layer to form a strong, dimensionally stable panel. The difference is that whereas plywood is made of thin veneers, CLT is made up of lengths of solid timber, to create mass-walling panels up to 0.4 meters thick, 3 meters tall and 24 meters long.

The advantages of CLT include:

- excellent combination of lightness and strength, sufficient to enable multi-storey construction up to 10 or possibly more stories while permitting relatively light groundworks;
- good load distribution permits great freedom of design;
- high degree of dimensional stability for a timber construction method;
- good durability if well-maintained;
- a solid form of construction, which may be more appealing to some clients;
- good acoustic insulation properties;
- superior fire-resistance relative to stick-built timber or some forms of steel construction (chars rather than combusts, so that the char layer slows the burn rate);
- some intrinsic thermal resistance and thermal mass;
- natural moisture-regulating capacity, helping maintain a comfortable indoor environment;
- rapid construction times requiring relatively small amounts of site labour;
- highly sustainable, enabling the use of relatively low-grade timber to produce a very strong and homogeneous structural form;
- good substrate for first- and second-fix items.

However disadvantages of CLT include:

- vulnerability to decay if moisture enters the structure, so;
- should not be exposed to excessive damp or rain during construction;
- must have rainproof external cladding;
- requires appropriate detailing and consistent maintenance;
- can be used only above DPC level;
- uses large quantities of timber relative to other forms of open-frame or stick built timber construction;
- greater cost relative to conventional timber panel systems;
- currently few UK-based manufacturers, meaning that long-distance transport adds to costs and reduces environmental benefits;
- construction on restricted sites may pose challenges.

Closed panel timber frame

Panelised timber construction is already one of the most common forms of offsite construction, with homebuilders using pre-fabricated timber panels in thousands of new houses. Currently, most panelised timber construction is open panel – consisting of a timber panels that combine solid timber studwork with external timber sheeting, usually made of oriented strand board (OSB), a form of composite board. Insulation, moisture and vapour barriers, interior finishing such as drywall, and exterior cladding, as well as windows and doors, and are usually fitted subsequently onsite.

Closed panel systems bring the panel to a much higher level of completion, including at least insulation and a vapour barrier, but often the internal and external cladding as well. The latest generation of ‘advanced panels’ used factory-injected insulation, usually polyurethane (PU) foam but sometimes other products such as cellulose fibre, that completely fill every crevice in the panel to ensure that there are no thermal bridges.

Some of these panels can be manufactured with windows and doors preinstalled to further ensure high levels of thermal performance and to reduce the amount of site work needed. Compatible floor and roof cassettes are also often available as part of closed panel systems, providing a complete ‘one-stop shop’ building solution.

Closed panel systems have a number of advantages:

- the prefabricated panels can then be rapidly assembled onsite by a small team of labourers using basic carpentry and joining skills;

- structures can be erected and weather-tight within days or even hours, enabling internal fitting to commence almost immediately;

- if installed correctly, closed panel systems result in very high standards of thermal efficiency - indeed, some close panel systems claim energy efficiency grade A ratings, enabling comfortable internal temperatures to be maintained with minimal direct heating;

- advanced panels are highly efficient in their use of materials, using much less wood than solid timber systems.

Disadvantages may include:

- a perception that this is a ‘light’ system of construction, potentially creating difficulties in cultures where there is a preference for ‘solid’ construction;

- more costly in terms of materials;

- vulnerability of timber construction to decay when exposed to moisture;

- need for extremely precise groundworks and component assembly if thermal bridging is to be avoided and airtightness maintained;

- lack of experienced construction crews;

- need for very careful installation of building services to avoid comprising thermal performance;

- acoustic performance inferior to masonry or solid timber systems, making this form of timber construction less suitable for some noisy environments.

High technology glazing[32]

A major focus of research and manufacturing in recent years has been improving the environmental performance of glazing, traditionally regarded as the weak spot in buildings thermal efficiency. In hot summer weather, large windows let in visible light, but also allow heat to build up because they are also transparent to infra-red radiation. In cold weather, meanwhile, glazed panels are relatively poor insulators and therefore make buildings more difficult and costly to heat.

Attempts to remedy this include thermotropic glass, which is formulated so that it changes colour as light intensity increases, thus helping to control glare and overheating; unfortunately, this tends to be hazy, making it less suited to areas where the glass needs to be fully transparent. Photochromic glazing is also designed to change colour in response to light intensity, but does not have the same transparency issues. Both of these types of window have the disadvantage of cutting out *all* intense sunlight, meaning that in winter they cannot take advantage of the heat capture potential offered by glazing.

Recent developments have focused on overcoming these disadvantages, for example by using Fresnel lenses to exclude infra-red energy from high summer sun while allowing it in from low winter sun. The GlassX system combines utilise this within a triple-glazed system in which the inner void of the glazing is filled with a transparent, heat-storing phase change material. This means that heat is absorbed from sunlight during the winter daytime and then gradually released overnight, creating windows that actively contribute to the thermal performance of the building.

Lightweight Steel-frame (cold rolled)

Lightweight steel frame (LSF) construction is an increasingly well accepted addition to the repertoire of steel frame construction techniques. LSF construction is very similar to timber framed construction, only the timber components are replaced with galvanised sections made of steel sheet. The sheet is rolled very thinly, around 1.2-3.2mm, and is then cold-formed into C-, Z- and U-sections.

The sections are then used to construct into structural frames for walls and partitions either by ‘stick-building’ using pre-cut components or through assembly of offsite manufactured panels or modular volumetric units.

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[32] http://www.bath.ac.uk/cwct/cladding_org/gib99/paper23.pdf
http://greenspec.buildinggreen.com/blogs/high-tech-glazing-phase-change-material

LSF panels can be used as load bearing members in structures up to 12 stories high, or as external walling or infill panels for an independent structural skeleton. In infill and panelised systems, the pre-assembled panels are inserted into U-section ‘tracks’ attached to the bottom and top of each section of the wall.

The use of LSF has increased substantially in recent years for commercial and low-rise residential projects. LSF is also one of the commonest materials for the construction of volumetric modular units, such as bathroom and kitchen pods. Its advantages include an excellent design life (for ‘warm frame’ construction where the steel frame is inside the insulation the industry estimate is around 250 years). The materials used are recoverable and recyclable, helping to mitigate the carbon emitted during the production and processing of the steel components. The material is not flammable, although its light construction means that it must be protected from fire in order to meet building code requirements as it will, if subjected to prolonged high temperatures, potentially suffer catastrophic failure.

Modular Volumetric Construction

Modular volumetric construction is a form of construction that manufactures whole rooms or spaces offsite. Modular volumetric construction can make use of a wide variety of construction techniques. However, the most common and flexible is light steel frame construction, due to its combination of strength and lightness (Rogan *et al.,* 2000). The volumetric units are consequently relatively easy to transport; they can be constructed into substantial structures (up to five stories with ordinary light steel units, and up to twelve stories high with appropriate engineering modifications), or slotted into an independent structural frame made of, for example, pre-cast concrete or steel posts and beams.

Volumetric units can be completed to the final level of internal finish, will usually incorporate all services, and may even have all external claddings and renderings pre-installed. The result is that all the main component units of an entire building can be made offsite. The units then function as ‘building blocks’ that are fitted together to produce completed buildings, thus attaining very high levels of speed and ease of construction.

These techniques are particularly applicable to commercial construction projects, especially where large numbers of very similar or identical buildings are required. There are two main reasons for this. First, the repetition of identical or very similar units and structures enables the cost per modular unit to be reduced – ‘economy of scale will increase with greater standardisation and production line efficiency. The second is many commercial (especially retail or hospitality) clients typically wish for fast completion times for outlets, as extended construction time (and therefore lost opening time) is typically viewed as lost operating profit. The pioneer of this approach in the UK has been McDonald’s Restaurants, who have constructed and opened a restaurant, on pre-prepared foundations, in only 13 hours (BRE, 2003). Modularised volumetric construction is now extensively used in the hotel and retail sectors, but has been consistently identified in the research as an area that is likely to see substantial growth in the future.

Reverse Wall Construction

This is a form of timber panel construction in which the timber panel (usually OSB faced with plasterboard) is attached to the *inside* rather than outside face of the studs, while the external surface of the panel is made of moisture resistant plasterboard. In this form of construction, the internal panel functions as a vapour barrier, meaning that the use of separate, applied vapour barriers is not necessary.

Service Pods

The most widely-known and recognised form of offsite construction is the use of pods containing domestic services, usually bathrooms or kitchens, but in a more commercial setting may also include plant rooms for large buildings. These pods be constructed as light steel frame units or moulded from high strength composites such as Glass Reinforced Plastic (GRP - fibreglass) or polypropylene. The main characteristic of these pods is that they are delivered complete, incorporating all plumbing and electrical services, and can be supplied with or without fittings. Since the installation of bathrooms and kitchens is one of the most expensive and complex parts of the normal building process, the pre-fabrication process is of value by enabling it to be undertaken in a highly predictable way to dependable quality standards and to defined costs.

Some service pods are made using essentially the same hand building skills and techniques as traditional on-site construction. However, more modern pods are being produced in high volume manufacturing facilities that use automation and advanced techniques to increase precision and reduce the role of traditional building trades.

Solid Timber Frame

At the same time as innovative offsite methods of timber construction have grown in importance, there has also been a revival in the use of solid timber frame construction, also known as heavy timber frame. Solid timber frame is essentially the heir of traditional timber-framed construction, making use of thick (approximately square section), widely spaced posts and beams to form a highly robust and durable structure. Hardwood, especially green (unseasoned) oak, is the most traditional form of solid timber framing material, but a wide range of timber types can be used, including chestnut, Douglas fir, larch, pine and glulam. Glulam is the most modern of these materials, and consists of thin layers of wood glued together to form a solid structural member. Glulam beams can be formed into custom shapes and have greater dimensional stability and structural consistency than natural timber.

Solid timber frames can be held together using either pegged joints or modern steel brackets. The former approach is a contemporary development of traditional medieval carpentry techniques and tends to produce 'over-engineered' structures. The latter is an entirely modern approach which often uses the materials in far more structurally demanding ways that require formal engineering calculations.

The frame is cut offsite and then taken to the construction site to be assembled either by team of skilled carpenters (if it is a traditional frame) or by a competent team of construction operatives (for more modern steel jointed approaches). The frame can then be in-filled with a wide variety of materials.

Solid timber frame is especially popular with self-builders seeking a premium product with a distinctive aesthetic that is often part traditional and part modern (Ross *et al.,* 2007).

Structural Insulated Panels

Structural insulated panels consist of a 'sandwich' of two sheets of structural board – usually OSB, plywood or steel sheet – attached to an insulated foam core. SIPs are extremely light and strong, and can be used to create large wall panels that can be pre-cut to size and may also have openings cut for windows and doors.

Other existing and developing technologies with future potential

- modular volumetric whole buildings (such as fast food restaurants);
- pods in the form of volumetric units such as kitchens or bathrooms;
- concrete;
- solid timber frame;
- strawbale;
- SMART materials – embodied with characteristics that mean the amount of carbon used to form the product's components can absorb carbon;
- insulation materials that absorb and disperse heat from buildings;
- recycled fibre materials;
- smart glass, i.e.to control amount solar gain, heat gain and heat loss depending on amount of sunlight and lining for inside of buildings that adapt to high temperatures and humidity to temper the internal environment – either controlled passively or as part of an active system;
- pre-insulated wall panels.

Appendix C: Existing Provision

There are a series of innovation centres within UK universities that are undertaking cutting-edge research in innovative building materials and technologies, including:

- Edinburgh Napier University: Centre of Offsite Construction and Innovative Structures (SOCIS);
- Loughborough University: Centre for Innovative and Collaborative Construction Engineering; Innovative Manufacturing and Construction Research Centre;
- Northumbria University: BIM Academy;
- University of Reading: Technologies for Sustainable Built Environments Centre;
- University of Salford: Centre for Construction Innovation; Salford Centre for Research and Innovation in the Built and Human Environment.

These centres, amongst other Higher Education Institutions, offer some provision which encompasses MMC and offsite.

British Research Establishment

- How to identify and survey Modern Methods of Construction. Six-hour CPD day course for qualified professionals.

Birmingham City University

- MSc Integrated Design and Construction Management – a course with a focus on whole life performance of buildings
- PgCert / PgDip / MSc Environmental Sustainability (Design and Construction)

Coventry University

- MSc Low Impact Building Performance and Evaluation
- Research degrees in construction technologies (e.g. timber composites)

University of Cambridge, Cambridge Centre for Smart Infrastructure and Construction

Research-oriented centre with a mission to deliver training (particularly ‘training the trainer’), but with no regular offer at present.

University of Cambridge, Laing O'Rourke Centre for Construction Engineering and Technology

MSt Construction Engineering Master's (CEM). Forthcoming courses intended to cover 'the latest innovations in analysis, design and materials technology. Sustainability and whole life performance will necessarily form core components interwoven through all aspects of the course'.

Edinburgh Napier University Centre of Offsite Construction and Innovative Structures (SOCIS)

No specific training or courses in MMC. However, the centre staff contributes to the teaching of modules within the following courses:

- Principles of Civil Engineering (1st year, BSc and BSc (Hons);
- Methods of Construction (3rd year, BSc and BSc (Hons);
- Forensic Engineering (5th year, MEng, and MSc in Advanced Structural Engineering).

Leeds Metropolitan University

No specific training or courses in MMC, although staff members have research interests in the field. However, current degree courses do include consideration of BIM , e.g.

- BSc (Hons) Construction Management – BIM modules at Levels 5 and 6;
- BSc (Hons) Architectural Technology – Second year BIM course;
- MSc Advanced Engineering Management – includes module on Eco Engineering (Semester two) (20 Credits), which 'Covers environmental issues such as recyclable material selection, design for minimum power used in process, minimum material required (FEA), Design for Manufacture and Assembly'.

Loughborough University, Centre for Innovative and Collaborative Construction Engineering

Leading centre in the UK for research into construction technology and innovation, offers:

- EngD: Four-year doctorate combining a core of three compulsory courses with a research project (and a full dissertation project for those who do not have an MSc or MEng) along with 'suitable' modules from the MSc programme within the Faculty of Engineering (see below).

Loughborough University, School of Civil and Building Engineering

The school offers courses dealing with innovative construction technologies, but not specifically with MMC:

- MSc Low Carbon Building Design and Modelling;
- MSc Low Energy Building Services Engineering.

Loughborough University, Innovative Manufacturing and Construction Research Centre

Entirely research focused, and no longer active (sustained by special grant programme from 2001-2011)

Northumbria University BIM Academy

- Runs 'BIM seminars' for practitioners;
- Autodesk Revit training – CPD in one of the standard BIM software packages;
- MSc Building Design Management and BIM (run jointly with the School of the Natural and Built Environment).

Plymouth University

- HNC/FdSc Sustainable Construction and the Built Environment

University of Reading, Innovative Construction Research Centre (ICRC)

Recently closed.

University of Reading, Technologies for Sustainable Built Environments Centre

D.Eng: Four-year doctorate combining industry project with modular courses; includes modules on:

- Integrated Building Design: Engineering Intelligence into Buildings;
- Sustainable Design Construction and Operation;
- Applied Informatics;
- System Analysis and Design.

University of Reading, Design Innovation Research

Occasional workshops and seminars with a research focus

Recent undergraduate placement in Immersive Visualisation of Building Information Models

University of Salford, Centre for Construction Innovation/Salford Centre for Research and Innovation in the Built and Human Environment

Does not itself offer sustained formal training, but provides access to HND, CPD, BSc and MSc programmes at the School of the Built Environment, University of Salford, including:

- BSc (Hons) Architectural Design and Technology;
- MSc BIM and Integrated Design.

University of Salford, School of the Built Environment

Formerly offered MSc and CPD courses in Advanced Manufacturing in Construction

University of Westminster

Offers a range of undergraduate and postgraduate full and part time courses covering:

- BSc Architectural Technology;
- BSc Building Engineering;
- BSc Building Surveying;
- BSc Construction Management;
- MSc Building Information Management;
- MSc Continuing Professional Development.

Appendix D: Case Studies

Case Study 1: Straw bale construction, Modcell and the University of Bath

Rationale

Straw bale construction is a method which uses straw bales either as a loadbearing structure or as an infill to an independent structural system. Straw is a material that is warm, renewable and durable, it is low in embodied energy and has a negative carbon footprint, absorbing CO^2 from the atmosphere. When used for building, its high insulation values should result in significantly lower energy consumption.

Advantages	Disadvantages
• Renewable • Sustainable • Readily available as a by-product of arable farming • High insulation values • Acoustically insulating • Strong enough to support a two storey building	• Materials can require long term dry storage • If there is any element of onsite construction managing tarpaulins is very heavy work • Dealing with novel materials perceived as a high risk by financiers and wider construction industry • The small scale of production is expensive compared with other building methods making it 5-10 per cent more expensive • Lack of certification barrier to uptake and adoption

There is enough straw available in the UK to build 600,000 homes year on year, more than 5 times the size of the current new build housing market.[33] In addition the thermal properties of straw can reduce emissions generated through the heating and cooling of buildings. There is more CO^2 equivalent banked in the form of carbon in straw than is emitted through the process of planting, harvesting, baling and constructing a building using straw.

Methods of straw bale construction

Nebraska method	Timber framed studwork	Cassettes built off site	Rendered panels
• Load bearing system whereby bales are laid as blocks in stretcher bond and pinned together with sharpened sticks. Render is issued on internal and external faces to achieve a composite action	• Straw bales are used as the insulating infill between timber studs which are built in situ	• In some instances of straw bale construction straw is used in pre-fabricated timber studwork cassettes that are built off site	• This method uses prefabricated panels that are rendered off site

[33] http://www.architecture.com/SustainabilityHub/Designstrategies/Earth/1-1-1-8-Strawbaleconstruction.aspx

Prefabrication and straw bale construction

The traditional use of straw bales onsite, as large building blocks, has proven successful among people building their own homes (i.e. self-build projects) but there is not, at present, a wide uptake by the mainstream construction industry. The use of straw bales in factory manufactured building panels, both for cladding and load bearing walls, offers an innovative solution taking advantage of the benefits of straw, whilst addressing many of the concerns around the practicalities of straw bale construction.

There are two methods of using straw bales in offsite construction. The most common is to manufacture panels in a centralised factory and ship the product out to be erected onsite. This method typically makes use of a permanent staff of both skilled operatives and low skilled workers. In the UK proprietary panels made by Modcell have undergone structural and fire resistance testing, acoustic and thermal performance testing by the University of Bath. The image below shows a depot belonging to York City Council that was built by Modcell using pre-fabricated straw bale panels.

Photo redacted due to third party rights or other legal issues

Image courtesy of Modcell

The second method of prefabrication is what is commonly termed the "Flying Factory model". This method of manufacture is becoming increasingly popular with straw bale builders. As straw is essentially a cereal crop it can be grown in a wide variety of locations throughout the UK. Using the Modcell model, local 'flying factories' are created on farms, usually within ten miles of the construction site and then fitted together on pre-constructed foundations.

In addition to the ecological and sustainability benefits this model can bring community benefits by employing local workers in the construction and erection of the panels. Frames are made from glued together timber off cuts which are also sourced locally.

Modcell prefer to employ semi-skilled labour to keep the cost and build times within

agreed parameters. One of the benefits of offsite construction is perceived to be the speed with which it can be erected. Where local labour is used in the flying factory models, it is often the case that clients accept a marginally higher cost incorporating a training period and set up costs of the 'flying factory'.
Skills and qualifications required
Skills used in this context move away from traditional construction craft skills. There is an emphasis on drawing and planning as well as on fitting and erection onsite. The majority of those with skills at Level 4 and above are employed in design, operational or managerial roles. However, the bulk of the workforce is employed at factory and erection level. Although the work within the factories is often repetitive and carried out along a process manufacturing model there are requirements for skilled and experienced labour in training and supervisory capacities. Commonly these roles are filled by those who are highly skilled and trained in traditional methods of construction such as carpentry and joinery. Those responsible for erecting the buildings are also highly skilled individuals. Each building may have different specifications and is built on a different plot meaning that the workers responsible for putting it together have to be experts in this field.

Vocational Qualifications:	**GCSE and A Level Qualifications:**	**Undergraduate and post graduate qualifications:**
Although it is not always essential for the factory workers or those erecting structures onsite to hold formal qualifications, many employers value vocational qualifications in traditional building crafts, specifically carpentry and joinery for erectors and manufacturing skills are considered desirable for those who work in the factory settings.	For the majority of permanent operational management and business roles, including design, marketing, and project management a minimum of 5 GCSE at grade C and above are required as well as 4 A levels to include Maths at A* Level for design engineer roles.	Although by no means new the construction industry and wider market have yet to fully embrace the possibilities of straw bale construction. For this reason there are few universities that include this method in their courses. The University of Bath is a notable exception with modules on prefabrication in both undergraduate and postgraduate qualifications.

Case Study 2: Skills needs for offsite timber frame construction

Rationale
Using a prefabricated timber frame results in much faster construction than traditional brick and block construction. A timber frame is usually erected onsite by the supplier's own carpenters; taking days rather than weeks. It is estimated that across all the developed countries, timber frame accounts for around 70 per cent of all housing stock. In the UK the capacity is around 35,000 – 40,000 units each year.[34] *One of the main benefits in offsite timber frame construction is the speed at which erection can be carried out. We erected four new classrooms at a school in just less than 11 weeks, as a traditional construction project it would have taken months. Reducing timescales reduces disturbance and hazard.* **Timber frame manufacturer interviewee**
Evolution
Wood has been one of the mainstays of the UK construction industry for centuries and timber framed houses built in the twelfth century are still around today. The industrialised housing boom of the 1960s and 70s brought about a dramatic growth in the market share of timber framed houses and by the early 1980s 27 per centof of new houses in the UK were built using timber frames.[35] At present Scotland maintains the greatest market share of timber framed building at around 40 per cent of all new housing.[36]
Methods of timber frame construction

[34] Sustainable Homes online briefing on timber frame housing: www.sustainablehomes.co.uk/Portals/63188/docs/Timber%20Frame%20Housing.pdf accessed 02/09/2013
[35] Figures provided by National House-Building Council.
[36] Sustainable Homes: Timber Frame Housing

Stick built	Small panel	Large panel
• Materials are cut off site and put together onsite. This is not a widely used method in the UK and is generally restricted to post and beam type construction	• Timber studs are made into panels, usually of oriented strand board (OSB) which is coated in a breathable membrane. The panels are transported onsite and manoeuvred into position to be nailed together	• Sometimes referred to as platform frame because the panels form walls which fit together on which the next storey wall panels sit

Manufacturing timber panels

In the UK there are a number of manufacturing systems in use including:

1. Open panel frame manufacture

Open panel is a term that refers to the primary support structure of the panel which is made up of vertical studs to carry a downward load and sheathing which braces the panel. The panels are open so that they can receive dry lining materials, electric wiring and so on. Open panels do not have insulation, vapour control layers, internal boarding or services fitted in a factory environment.

2. Closed panel frame manufacture

Insulation, vapour control layers and internal finishing boards are all finished in a factory in the manufacture of closed panel timber frames. Often windows doors and services such as plumbing and electrics will also be pre-fitted in the factory. Closed panel frames generally allow more value to be added in the factory and because of this service runs for plumbing and electricity have to be signed off in advance of the manufacture of the unit.

One of the latest innovations in the manufacture of timer frame panels is the reverse wall. This places the Oriented Strand Board (OSB) on the inside face of the panel which makes it more robust and acts as a vapour control layer. The external part of the panel can be made of a number of components such as moisture resistant plasterboard or a breather membrane, all of which can be applied for a low cost within a factory environment.

3. Volumetric timber frame manufacture

For walls, greater prefabrication means a move towards closed panel systems and possibly towards full volumetric units, although uniformity and size constraints are likely to limit volumetric buildings to specific markets, including hospitals, student accommodation and prisons etc., where rooms are often all the same. Using this method, large elements of the structure of a building can be manufactured and assembled off site to form whole rooms. In some instances these can include all furniture, carpets and fittings and are craned into position where the final connections of electrics and plumbing are made.

4. Structural Insulated Panels (SIPS)

Like timber frame, SIPS are a factory-built, panelised building system that arrives onsite on a lorry. Whereas a traditional timber frame uses studwork for loadbearing SIPS rely on gluing insulation between two sheets of building board, usually OSB. The benefits of this system include excellent levels of insulation and air tightness. It can also be erected very quickly because there is very little onsite work required. The panelised roof parts mean that it is easy to construct attic rooms in the roof and because the insulation is built into the system there is not only a high level of factory level quality control, but also walls can be narrow, which can be a benefit where there is not much space available.

Skills Needs

Within each area of the design, manufacture and erection process there are a variety of skills needs. Some of these needs are reasonably well catered for and are common across the construction and engineering industries, others, such as those listed below, are more specific to modern methods of construction and in particular to timber frame construction methods.

• Dynamic insulation: hole drilling and vent • Insulation fitting onsite of walls and roofs • Thermal bridging detailing: awareness and application • Waste water heat recovery: installation and safeguards against legionella	• Procurement and ordering of materials • Task planning and management of inter dependencies • Governance of quality, time and cost • Mechanical ventilation installation and commissioning: workmanship, positioning and clash detection

The use of CAD and advancements in technology has meant that many elements of timber frame manufacture are carried out by complex machines which require skilled operators. Although in terms of volume this type of construction may require a smaller workforce the skills used within the workforce are often complex and highly specialist. Many of the product development skills required within the factory environment are transferable and training around sequencing of manufacture and the requirements therein is critical.

Process manufacturing is not a low skilled task because it is repetitive. You wouldn't say that a highly skilled technician working in an automotive factory was low skilled because they aren't building one off designs, off site factory manufacture has a high skill requirement, even where it's a case of operating, or setting a machine there is a requirement for a skilled individual who knows what they are doing to be in charge.

User of timber frame technology interviewee

At a senior level architects and project development directors are hugely important to the build process from beginning to end. Most organisations report that a project or development director should be qualified to degree level in a subject such as construction technology.

Many of the job roles requiring qualifications at Level 4 and above within the timber frame industry fall within the categories of technical and managerial. Contracts and site managers are highly sought after by employers as are engineering and technical qualifications.

There is a need for highly skilled individuals such as engineers, designers, estimators and contracts managers and training provision doesn't meet these needs in the timber industry. Timber is completely missed at university level. It accounts for about one week in a three-year degree course

User of technology interviewee

There are four main areas of expertise within the timber frame sector; design, construction, commerce and sales and customer care. Each category contains a broad range of specific job roles across all levels from generalist to highly specialist.

Design

- Technical Management
- Architect
- Architectural Technician
- Design Consultan
- Timber Frame Designer

Construction

- Contracts Manager
- Site Manager and assistant
- Site Trades
- Subcontractor
- Health and Safety Manager
- Factory Manager
- Factory Operatives

Commerce

- Commercial Manager
- Site Surveyor
- Buyer

Sales and customer care

- Sales Manager
- Customer Service Manager
- Sales Administrator
- Sales Consultant
- Marketing Executive
- Customer Service Operative

Case Study 3: Job roles required for offsite construction in the concrete sector

The UK cement industry: ready mixed and precast concrete

90 per cent of the UK's cement is manufactured in Britain and no school, house, road, hospital or bridge could be built without it.

The UK cement industry operates 12 manufacturing and two grinding plants, producing ten million tonnes of Portland cement a year. There are over 800 precast concrete factories across the country; this local network means travel distances and fuel used during haulage are minimised.

The environmental impact of concrete, its manufacture and applications, is complex. Well-planned concrete construction can have many sustainable benefits and the recycling of concrete is increasing in response to improved environmental awareness, legislation, and economic considerations. There is a growing interest from both the academic and industrial sectors in reducing carbon emissions related to concrete.

Ready mixed concrete was one of the first methods of offsite construction that was widely adopted. It has been around for decades but since the 1980s the industry has been expanding steadily. In the 1950s concrete was mixed onsite but these days over 90 per cent is ready mixed.

Ready mixed concrete is manufactured in a factory or batching plant and delivered onsite, often in a transit mixer truck. The mixture is precise, developed to suit the needs of a specific project or job within a project. It is manufactured under controlled operations and transported and placed at site using sophisticated equipment and methods. Manufacturing ready mixed concrete requires technology including transit mixers, batching plant technologies, visualised production management software and programmable logic controllers.

Precast concrete is produced by casting concrete in a reusable mold or "form" which is then cured in a controlled environment, transported to the construction site and lifted into place. There are many different types of precast concrete forming systems for architectural applications, differing in size, function, and cost.

Precast concrete provides the manufacturers with the ability to produce a wide range of engineered earth retaining systems. Modular paving is available in a rainbow of colours, shapes, sizes and textures, these versatile precast concrete pieces can be designed to mimic brick, stone or wood.

Insulated concrete wall systems provide superior thermal efficiency and optimal energy performance over the life of the building.

The technology used in this process is all about monitoring of production and lots of quality control procedures – concrete can carry many tonnes

Innovator interviewee

Uses and benefits of ready mixed and precast concrete

Ready mixed and precast concrete provide the following uses and benefits:

- Precast concrete can carry pre-installed services;
- Services can be cast within a precast element or panels can include connection plates;
- Microchips can be embedded in precast concrete to log data on movement or stress;
- Better quality of product than with onsite mixed products due to increased accuracy of calibration of components;
- Precast concrete is made from a range of materials, which can be combined to produce different properties. This means that precast can be porous or impervious; it can float or sink, be heavy or light;
- Unused elements can be used elsewhere. Scrap created at the building site can be collected and broken up to create aggregate;
- There is no need to store raw materials onsite;
- Reduction of time needed onsite;
- Precast concrete moulds can be stored to allow later replication;
- Precast products arrive ready for installation and can be scheduled to arrive ‘just-in-time’ so they can be lifted directly into place;
- All the materials that go into precast concrete products come from natural and recycled sources;
- Today’s precast factories are clean, efficient and many use computer-controlled processes for batching, mixing and casting. Working in a factory means excellent resource efficiency;
- A centralised ready mix concrete batching plant can serve a wide area.

Job Roles

Within the ready mixed concrete sector high level job roles are most usually based in technical centres. Most companies operating within this area will have either one national technical centre (if they are a reasonably large organisation) or often smaller regional centres.

The concrete industry is labour intensive, however those skilled to Level 4 and above are in the minority. The chemistry and mineralogy of cement is complex. In the production and manufacture of both precast and ready mixed concrete there are a number of essential skills including:

- Ability to use computer software for data analysis and report writing;
- Practical skills in the recycling of industrial waste products in concrete;
- Ability/capability to work at the interface between material science and civil engineering;
- Ability to contribute to broader management and administrative processes;
- Research and laboratory skills in order to develop sustainable, lower carbon, precast concrete;
- Common job roles within the industry at Level 4 and above are Technical Managers and Directors and Laboratory Managers and Technicians.

Technical Managers and Directors

Concrete technologies are widely acknowledged within the construction and engineering industries as recognised engineering disciplines. The most common route into this field is via a degree route through an engineering discipline, employers are open to degrees including:

- civil engineering;
- chemical engineering;
- environmental engineering;
- structural engineering;
- engineering;
- mathematics and engineering.

Often Technical managers and directors will be members of the Institute of Concrete Technology. The institute offers designatory letters TechICT, AffIICT, AMICT, MICT, or FICT to appropriately qualified members, either by the institutes own examinations or by alternative qualifications routes.

Laboratory Managers and Technicians

Laboratory managers tend to be based exclusively within laboratories whereas technicians are often required to go on site visits, collecting material to analyse in laboratory conditions. Laboratory testing and site duties must be carried out in accordance with BS EN ISO 17025 to ensure that UKAS accreditation is maintained.

Managers are traditionally required to hold a degree in Chemistry although Environmental Science degrees are becoming more commonly accepted by employers. Technicians are often trained "on the job". Applicants to these roles are usually required to demonstrate the following skills and qualifications:

- HNC/HND in a relevant science subject;
- Knowledge of the Health and Safety at Work Act;
- Numeracy;
- Ability to read drawings;
- Good standard of written and oral communication.

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