BUILDING OFFSITE

AN INTRODUCTION

00

SYNOPSIS

FIGURE 1 OVERVIEW

TABLE 1 – OFFSITE HUB LEARNING MATERIAL CREATION PROCESS

TIER	ACTIVITY	OUTCOME
TIER 1 – INDUSTRY SPECIFIC	Undertake a rigorous skills audit of the industry partners to understand their immediate skills need(s).	Develop industry partners specific training material for their in-house training purposes using appropriate techniques.
TIER 2 – GENERIC	Run concurrent industry wide outreach activities and review other available literature and content.	Produce generic skills material for wider dissemination that does not impinge upon commercial sensitivities yet enhances industry partner reputation.
TIER 3 – MATRIX POPULATION	Engage with the wider skills community of Universities, Colleges and Training Providers as well as other external influential organisations.	Population of a skills matrix with international outreach potential.

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SYNOPSIS
The following document is an introduction to Building Offsite. Funded by the UK Commission for Employment and Skills (UKCES). The content was produced by an industry and academic collaboration of CCG (OSM), Stewart Milne Timber Systems, Edinburgh Napier University and Heriot Watt University in partnership with Architecture and Design Scotland (A+DS) (Figure 1). The wider UKCES project remit was to create a Scottish Offsite Construction HUB as a centre of expertise, responsible for defining and showcasing skills requirements and ensuring collaboration between professions. Following the success of the UKCES project, the HUB concept is to be taken forward by the Construction Scotland Innovation Centre (CSIC) to ensure companies across the industry have an understanding of the interaction between the principles of design, construction, manufacturing and engineering, and that they are all maintaining high standards. The CSIC Offsite HUB will continue to develop practical and interactive learning material to share sector-wide, applying the process developed via the project (Table 1), upskilling the workforce and creating high level training on managing and delivering offsite construction. This document provides a starting point for raising awareness of the principles of offsite construction among various stakeholders, in particular clients and designers. This was identified as a clear need through the project's skills needs analysis.

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FIGURE 2 WHAT IS OFFSITE CONSTRUCTION?

INTRODUCTION

The use of offsite is growing internationally due to improved customer perceptions, the introduction of government support initiatives and the success of various high-profile case studies (Goulding and Arif, 2013). The current value of offsite construction in the UK is £1.5bn and it is projected to grow to £6bn (UKCES, 2013), this equates to a 7% share of constructions' £90bn annual contribution to the UK economy (HM Government, 2013). In the UK offsite has been identified as a method of delivery for the Government 2025 Vision for Construction particularly given the housing shortage and regionally in Scotland there have been several Scottish Government led initiatives to actively promote offsite construction particularly in housing through demonstration projects and the Scottish Government's Greener Homes Prospectus and Greener Homes Innovation Scheme (Scottish Government, 2012 & 2013).

KEY POINT: *The 'Construction 2025' Strategy sets out the following aspirational targets (HM Government, 2013):*

1. ***LOWER COSTS:*** *33% reduction in both the initial cost of construction and the whole life cost of assets*
2. ***FASTER DELIVERY:*** *50% reduction in the overall time from inception to completion for new build and refurbished assets*
3. ***LOWER EMISSIONS:*** *50% reduction in greenhouse gas emissions in the built environment*
4. ***IMPROVEMENTS IN EXPORTS:*** *50% reduction in the trade gap between total exports and total imports for construction products and materials*

THE FOLLOWING ARE THE KEY TOPICS COVERED:

- **OFFSITE CONSTRUCTION:** Provide an overview of offsite construction its advantages and the barriers to uptake
- **BUILDING IN A FACTORY ENVIRONMENT:** production, automation, design for manufacture and assembly (DFMA) explained as well as environmental impact, structural, thermal, acoustic and management considerations
- **CASE STUDIES:** a series of exemplar case studies which showcase offsite construction for the delivery of affordable housing

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OFFSITE CONSTRUCTION

This section covers:

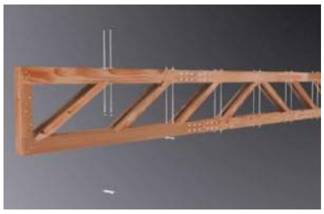
- What building offsite is
- Why building offsite has advantages compared to traditional on-site construction methods
- What the barriers are to building offsite

FIGURE 3 FORMS OF OFFSITE CONSTRUCTION

A) PANELISED FRAME – 2D (REF: SM NEW)

B) MODULAR/VOLUMETRIC – 3D (REF: SCOTIA MODULAR)

C) HYBRID SYSTEM – 2D+3D (REF: DAVID BLAIKIE UPDATE)



D) SUB-ASSEMBLIES AND COMPONENTS (REF: COSIS TIMBER TRUSS)

2.1 OVERVIEW (WHAT IS OFFSITE CONSTRUCTION? – FIGURE 2)

There are a range of terms which have been used for Offsite construction (Table 2) but fundamentally it is the manufacture and pre-assembly of construction components, elements or modules in a factory before installation into their final location of which 4 main overarching categories are considered (Abosaod et al, 2010; BuildOffsite, 2013) (Figure 3) that can if required be further broken down into additional sub-categories (Figure 4):

1. **PANELISED SYSTEMS ("2 DIMENSIONAL"):** also regarded as "non-volumetric preassembly" these are either classified as 'open' or 'closed' with open panels normally being non-insulated and closed panels being insulated. Enhanced panels are also referred to and these panelised systems have been enhanced beyond the closed state to include windows and doors, services (electrical or plumbing) or other finishes such as external cladding or internal lining.
2. **MODULAR OR VOLUMETRIC SYSTEM ("3 DIMENSIONAL")** is the term used to describe units prefabricated in a factory that enclose usable space that are typically fully finished internally, such as toilet/bathroom pods and plant rooms which are then installed within or onto a building or structure. Additionally this can include "complete buildings" where the completed useable space forms part of the completed building or structure finished internally (lined) and externally (clad).
3. **SUB-ASSEMBLIES AND COMPONENTS (2D OR 3D)** covers approaches that fall short of being classified as OSM systems. Typically, the term refers to simplified components like stairs, doors and windows which are manufactured in factories.
4. **HYBRID SYSTEM (2D + 3D)** a hybrid system is a combination of more than one discrete system or approach and is normally a combination of both volumetric and panelised systems.

Offsite construction is based on the principles of efficiency and quality employing manufacturing techniques in a factory applying a lean philosophy which is conducive to an environment for innovation. Consequently, offsite is often considered to be a "Modern Method of Construction" (A UK Government term used to primarily describe innovations in house building) (Table 3).

> ***KEY POINT:*** *Offsite construction is not limited to building components as it extends to other areas also, such as 'heating pods' which are mini-plant rooms that are fully commissioned and ready to use or 'modular electrical wiring' units which are pre-assembled electrical cabling systems.*

FIGURE 4 CATEGORISATION OF THE LEVELS OF OFFSITE CONSTRUCTION FOR 2-D ELEMENTS (WALLS, FLOORS AND ROOFS) AND 3-D ELEMENTS (SMITH ET AL, 2010)

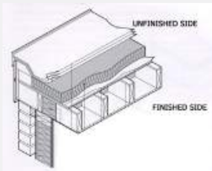
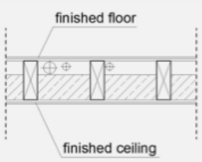
SUB CATEGORIES	CATEGORIES: 2D ELEMENTS						CATEGORIES: 3D MODULES	
	WALLS		FLOORS		ROOFS			
0		Uninsulated open panels: with first skin on only one side (e.g. OSB on one side of timber panels).		Uninsulated floor panels with decking only on one side and exposed joists/ beams.		Uninsulated open panels: with first skin on only one side (e.g. OSB on one side of timber panels).		Uninsulated modules whose surfaces have first skin on only one side.
1		Insulated open or closed panels without finished linings (e.g. SIPs).		Insulated floor panels without finishes.		Insulated open or closed panels without finished linings.		Insulated modules without finished linings.
2		Insulated closed panels finished on one side (either internally or externally).		Insulated floor panels finished on one side (either upper or lower side).		Insulated closed panels finished on one side (either internally or externally).		Insulated modules with finished lining on one side (either internally or externally).
3		Insulated closed panels fully finished internally and externally, with integration of services (i.e. with electrical and mechanical services, windows and doors).		Insulated floor panels fully finished on the upper and lower sides, with integration of services (i.e. with electrical and mechanical services).		Insulated closed panels fully finished internally and externally, with integration of services (i.e. with electrical and mechanical services, windows).		Modules fully finished on all sides, with integrated services (i.e. with electrical and mechanical services, windows and doors).

TABLE 2 OTHER “OFFSITE” TERMINOLOGIES

TERM	OVERVIEW
PREFABRICATED (PRE-FAB) CONSTRUCTION	Prefabrication can cover off-site prefabrication of materials and parts, prefabrication of components and subassemblies, as well as volumetric units or modules.
MODULAR CONSTRUCTION	Modularisation of construction is considered as a way of reducing complexity but still offering customised solutions. The Modular Building Institute (MBI) defines modular construction as an offsite process, performed in a factory setting, yielding three-dimensional modules that are transported and assembled at the buildings final location.
INDUSTRIALISED BUILDING SYSTEMS (IBS)	IBS is a term has been used to represent the prefabrication and construction industrialisation concept. The term has been used as a shift away from prefabrication with additional emphasis on improved productivity, quality and safety.
OPEN BUILDING MANUFACTURING	Open building manufacturing is the concept of applying production theory to construction employing standardised components that can be configured and assembled to provide a specific end result.
OFFSITE MANUFACTURE (OSM)	The manufacture of construction components or systems in a factory environment to be transported and assembled on site.

TABLE 3 CONSTRUCTION IMPROVEMENT TERMINOLOGIES

TERM	DESCRIPTION
LEAN PRODUCTION	The aim for perfection through continuous improvement is the foundation of lean production, a concept that stemmed from the production system of the Japanese car manufacturer Toyota. The principles of Lean are teamwork, robust communication, efficient use of resources and elimination of waste.
LEAN CONSTRUCTION	Construction is a project-oriented framework where objects or systems are being gradually enhanced by “trades” or “crafts” men who are not necessarily organised in a flowing manner. It is therefore more difficult to implement lean theory and the corresponding long-term strive for perfection given lean theory is applied to a series of “temporary” production systems which are linked to other temporary and permanent production systems for materials, equipment, labour, etc.
INNOVATION	The successful development or implementation of new ideas, products, processes or practices to increase organisational efficiency/performance.
PARTNERING	Partnering involves two or more organisations working together to improve performance through agreeing mutual objectives, devising a way for resolving any disputes and committing themselves to continuous improvement, measuring progress and sharing the gains.
MODERN METHODS OF CONSTRUCTION (MMC)	MMC are about better products and processes. They aim to improve business efficiency, quality, customer satisfaction, environmental performance, sustainability and the predictability of delivery timescales. Modern Methods of Construction are, therefore, more broadly based than a particular focus on product. They engage people to seek improvement, through better processes, in the delivery and performance of construction (Barker, 2006).

FIGURE 5 WHY USE OFFSITE CONSTRUCTION – THE ECONOMIC AND PRACTICAL ARGUMENTS

2.2 ADVANTAGES (WHY USE OFFSITE CONSTRUCTION? – FIGURE 5)

The factory, normally at a fixed location with good transport links, provides a controlled environment unaffected by climatic conditions employing a local work force. Moving to a factory environment with a secure supply chain utilising appropriate degrees of mechanisation offers a series of identified advantages (Gibb, 1999):

VALUE:

- **QUALITY**: consistency of process corresponds to improved quality and therefore more predictable product behaviour.
- **CUSTOMER SATISFACTION**: improved quality assurance results in reduced snagging and defects.
- **TECHNICAL**: higher levels of thermal and acoustic performance are achieved due to the quality assurance process employed and investment in research and development.

EFFICIENCY:

- **TIME**: Decreased construction time as a consequence of scheduling activities to take place concurrently rather than sequentially such as systems or modules being manufactured for ‘just-in-time’ delivery upon completion of site infrastructure including foundations and/or services (Figure 6).
- **WASTE**: the factory environment results in tighter control of materials and the use of CAD/CAM and automation allows material usage to be optimised. Therefore, the factory production of construction elements can have much lower resource inputs and reduced waste outputs compared with on-site construction with the substitution of tradition methods with offsite systems corresponding to a reduction in waste of between 20 and 40%, with the greater the fabrication the greater the savings (WRAP, 2008).
- **FLEXIBILITY**: the utilisation of a product family architecture of standardised component parts employing a mass customised approach ensures the desired level of variation to suit customer/client requirements.

SUSTAINABILITY (FIGURE 7):

- **SOCIAL**: the factory environment improves working conditions and offers a change in "construction culture" by providing a safe, clean place of work with improved job security and flexible shift patterns. This is of particular relevance when considering staff diversification - females account for approximately 13% of the total employment in the construction sector however 27% of "off-site" roles are filled by woman (CITB, 2010).
- **ENVIRONMENT**: "constructing" offsite in a factory corresponds to a more efficient use of materials secured through a qualified supply chain that are then utilised optimally to create components that are assembled on-site to form enhanced levels of building fabric performance.
- **ECONOMIC**: utilising a local labour force to add value to a localised supply chain for the delivery of a higher quality product efficiently is economically viable when executed appropriately.

KEY POINT: *Offsite construction can offer significant financial benefits through increased speed of construction which brings about reductions in construction programme and consequent reductions in financing costs. There are also significant cash-flow benefits to be had in terms of early completion and consequent early sale/rental income (Krug et al, 2013).*

FIGURE 6 - OFFSITE AND ONSITE CONSTRUCTION SEQUENCES (ADAPTED FROM THE MODULAR BUILDING INSTITUTE)

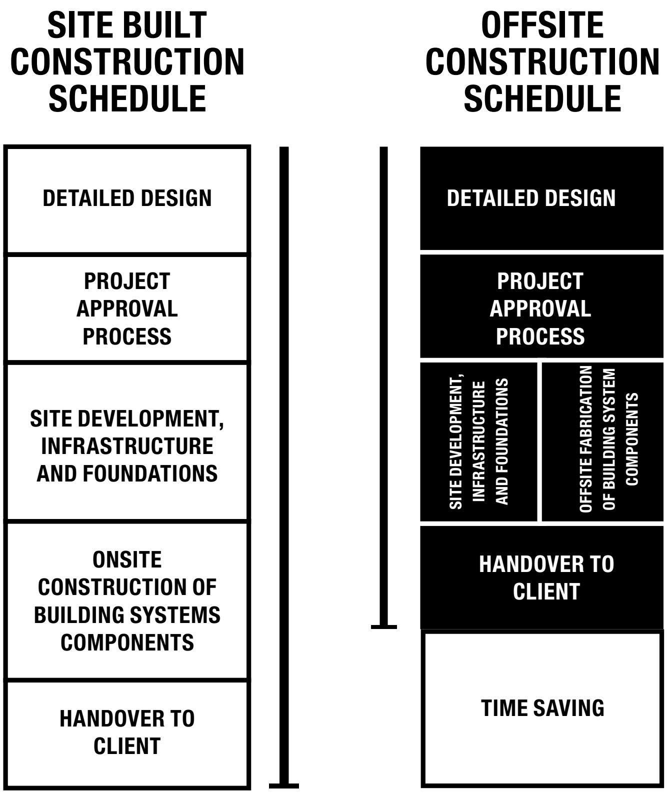
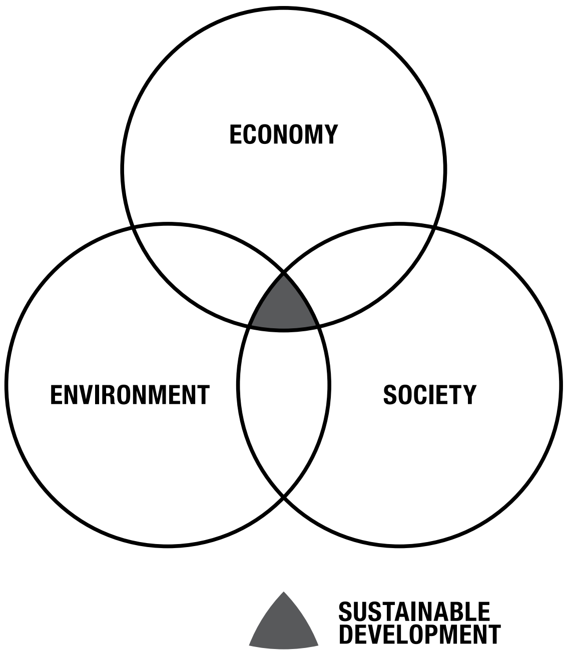


FIGURE 7 SUSTAINABILITY – TRIPLE BOTTOM LINE



2.3 BARRIERS (WHAT IS PREVENTING THE UPTAKE OF OFFSITE?)

Although offsite construction offers many advantages to traditional on-site construction there are barriers to its implementation including:

RESISTANCE TO CHANGE
Offsite is very much a change in construction culture and consequently has a different skill set requirement with an emphasis on holistic knowledge and an improved understanding of project management, scheduling and planning requirements. Given that this is the case a new approach to training and skills is needed at all levels providing improved pathways for career progression and enhanced levels of up to date information (Figure 8).

CAPITAL INVESTMENT
The higher levels of capital and technical approval costs for offsite construction requires investment decisions to be more informed demonstrating the added value of offsite construction (quality assured, just in time strategies, environmental impact and building fabric performance). Offsite construction therefore requires strong business leadership combined with operational management and a technical knowledge in order to address the misconceptions of the public, clients, lenders and insurers.

GUIDANCE AND INFORMATION
The concept of offsite is closely associated with manufacturing and draws on principles which seek to achieve improvements in quality and efficiency combined with reductions in waste. The guidance required and flow of information between design, production and assembly is therefore different from traditional construction and requires to be more integrated with a need for more holistic knowledge at all levels.

TRADITIONAL CONSTRUCTION BUSINESS MODELS
Offsite construction has a different cash flow model with a shift towards more upfront costs which in-turn may create differing finance arrangements. This is however offset by the speed of construction, particularly where revenues are more guaranteed i.e. social housing. Overall the cash conversion cycle is less, due to the shorter build time, associated with Offsite construction and this should be seen as a benefit as it can reduce overall development financing. However the current barrier is the need for greater understanding of the differing financial funding and cash flow cycles, when using Offsite Solutions.

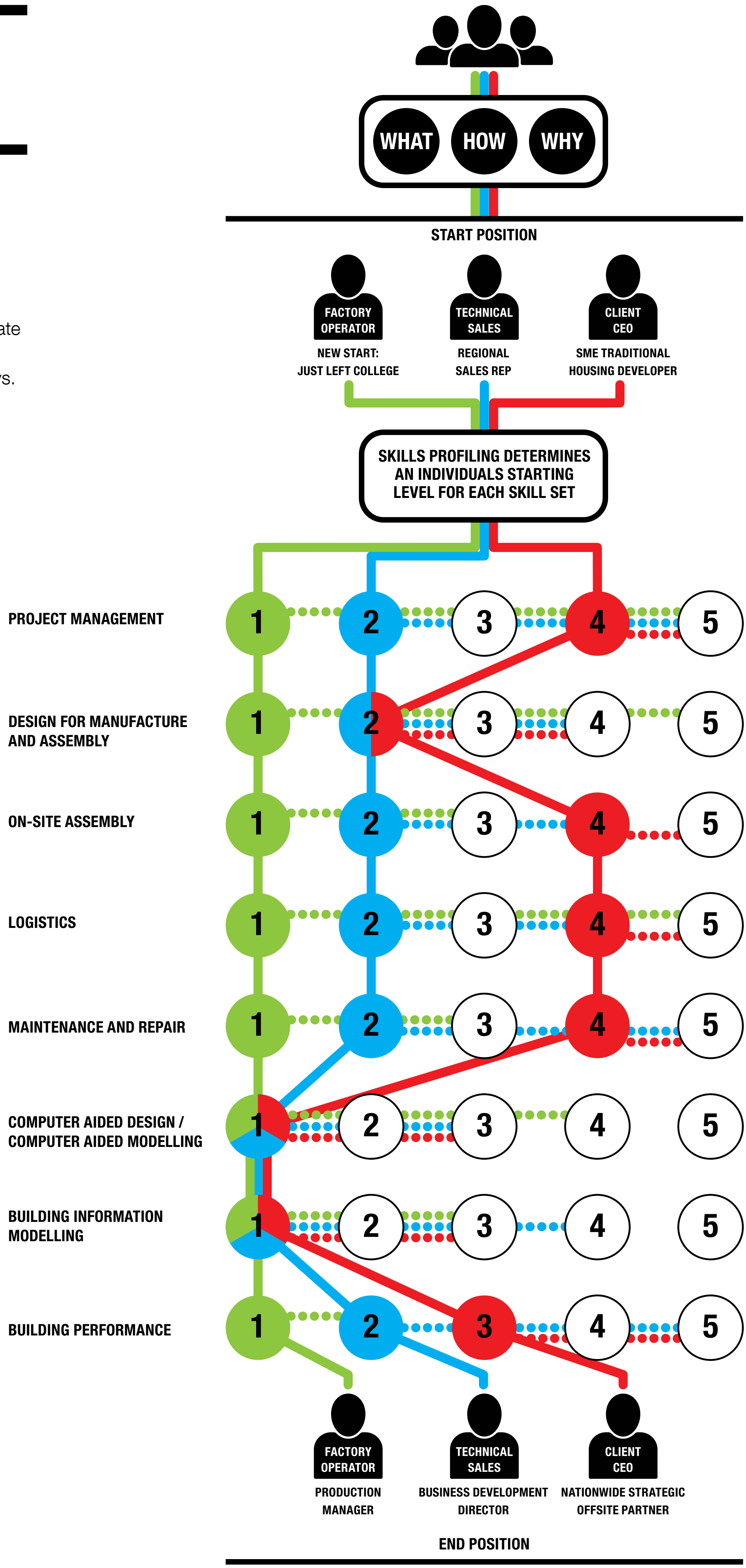
KEY POINT: *Increased levels of offsite result in standardisation and correspondingly automation and as a result there is the misconception that it results in the deskilling of traditional trades. Moving construction to a factory process corresponds to the need for upskilling at all levels because it is geared towards a more efficient approach in the delivery of the built environment employing modern design, fabrication, logistic and assembly techniques.*

FIGURE 8 EXAMPLES OF OFFSITE SKILLS DEVELOPMENT PATHWAYS

NOTE: There is a requirement to populate a matrix of skills material in order to inform the skills development pathways. Table 1 explains the approach taken by this project as part of this work in progress.

KEY

- 1 NOVICE
- 2 ADVANCED BEGINNER
- 3 COMPETENT
- 4 PROFICIENT
- 5 EXPERT
- ●●●●● PROGRESSION THROUGH THE SKILLS DEVELOPMENT PATHWAY



03

BUILDING IN A FACTORY ENVIRONMENT

This section covers:

- How building in factory is undertaken differently for constructing on-site
- How Design for Manufacture and Assembly (DFMA) is implemented
- How offsite construction creates more sustainable outputs
- How to manage the offsite process

3.1 PRODUCTION AND AUTOMATION (HOW IS OFFSITE CONSTRUCTION EMPLOYED? – FIGURE 9)

By moving the conversion of materials to form building components to a factory environment the onsite framework of activities, which are normally undertaken by a series of temporary organisations or subcontractors overseen by a construction manager, are now controlled by a production manager within a flow of processes and sub-processes. As a result the supply chain can be considered to be in two main parts (Figure 10):

1. **PREASSEMBLY FACTORIES**: purchasing, material handling, supplier involvement, prefab production, transportation and supply patterns etc
2. **CONSTRUCTION SITE**: orientation of trades, material delivery and storage, sub or final assembly etc

The level of offsite production and automation is dependent on the specifics of the project (housing, infrastructure, commercial, school and hospitals etc) or market to be supplied (i.e. private, public, one-off, mass production, etc) and the relative demands it places on the supply chain and logistical activities. However, by increasing the level of offsite activity in the factory environment less time will be spent on-site because activities can be run concurrently rather than sequentially such as the placement of foundations while components are being assembled (Figure 11).

***KEY POINT**: Current skills shortages across the sector and future strong competition from other industry sectors attracting school leavers will lead to further pressures on the industry resulting in labour costs increasing and project delivery times being delayed or extended. Offsite construction underpinned with modern skills and training initiatives can effect a change in construction culture which will result in a more productive environment alleviating future onsite sub-contractor supply chain issues.*

FIGURE 9 HOW IS OFFSITE CONSTRUCTION EMPLOYED? – CASE STUDY EXAMPLES

FIGURE 10 OFFSITE FACTORY AND ON-SITE ASSEMBLY

A) OFFSITE FACTORY PROCESS

B) ONSITE ASSEMBLY

3.2 DESIGN FOR MANUFACTURE AND ASSEMBLY (DFMA)

Automating the formation of building components, such as panelised wall systems and modularised room spaces in a controlled factory environment within a production flow process requires enhanced utilisation of information and communication technology (ICT) (Table 4). The production flow process can be linked to the computer aided design (CAD) and consequently be computer aided manufactured (CAM) using computer numerical controlled (CNC) machinery (Figure 12). The offsite assemblies should therefore be designed for manufacture and assembly (DFMA) (Table 2) utilising a series of standardised component parts accessed from a product family architecture that can be mass customised utilising CAD. Therefore, moving construction activities away from the site to a factory requires close coordination between factory and on-site operations for transport/logistics (consideration to be given to road haulage constraints – Figure 13), sequencing and on-site construction tolerances (allowable margin of error when interfacing construction phases). In addition, the building standards design and specification considerations (see Table 6 Building Standards – objectives) of a system requires to be informed by the capabilities of the manufacturing line and what it can accommodate with due consideration to the available components and parts via the supply chain. It has been demonstrated that when the correct balance is achieved, offsite out performs onsite construction, evidence of this has been provided for the housing sector (Construction Industry Council, 2013) (Figure 14). Additionally the on-site operations need to be taken into account with due consideration to allowable manual handling and whether a crane is required for the lifting or manoeuvring of building components. This is of particular relevance when considering more constrained sites where crane access may be limited which will either restrict crane use or weight of building components to allow for crane reach.

KEY POINT: *Design Freeze within an offsite construction process is important because late design changes can be costly due to the necessity for re-work. In traditional construction alterations to design can be accommodated more easily because operations are sequential and there is more room for manoeuvre should late adjustments be made.*

Given the requirement for robust communication the on-set of Building Information Modelling (BIM) is considered as an opportunity for offsite construction (Patlakas et al, 2015):

- **INCREASED DESIGN FLEXIBILITY** without increasing the production time or the manufacturing complexity;
- **ENHANCED VIRTUAL PROTOTYPING** by providing information-rich 3D models simplifying the process and lowering its costs;
- **CONTRIBUTION TO LEAN CONSTRUCTION** by minimizing the data exchange required between different platforms and systems;
- **IMPROVED ONSITE ASSEMBLY** via 4D modelling and visualization of the various stages of construction sites.

KEY POINT: *The UK Government as per the Construction 2025 Strategy (HM Government, 2013) is committed to the implementation of BIM for all centrally procured Government contracts from 2016. The emphasis is on the industry to meet this challenge given that BIM is seen as a key enabler to delivering more sustainable buildings, more quickly and more efficiently. Importantly BIM is also critical to the successful implementation of a wider offsite manufacturing strategy.*

FIGURE 11 COMPARISON OF ONSITE CONSTRUCTION AND ASSEMBLY OF OFFSITE SYSTEMS

A) LOOSE MATERIAL SENT TO SITE FOR FIRST FLOOR CONSTRUCTION

B) LANDING OF A PREFABRICATED FLOOR CASSETTE

TABLE 4 INFORMATION AND COMMUNICATION TECHNOLOGY (ICT)

TERM	OVERVIEW
COMPUTER AIDED DESIGN (CAD)	A computer aided design tool acts as a platform for the end user to produce a customised conceptual design based on the standard components that reflects their requirements.
COMPUTER NUMERICAL CONTROL (CNC)	A CNC machine is a production machine that is controlled electronically via computer technologies to reduce production time and increase quality and efficiency. The CNC machine therefore uses digital information to control the movements of tools and parts for processes such as cutting.
COMPUTER AIDED MANUFACTURE (CAM)	Controlling the manufacturing machines utilising computer software is regarded as computer aided manufacture, if this is integrated with the computer aided design it is regarded as CAD/CAM.
BUILDING INFORMATION MODELLING (BIM)	BIM is the utilisation of computer model data for the effective design, creation and maintenance of building assets and results in a collaborative way of working that is visualised via 3 dimensional computer models.

FIGURE 12 SIMPLIFIED CNC OPERATION UTILISING CAD/CAM

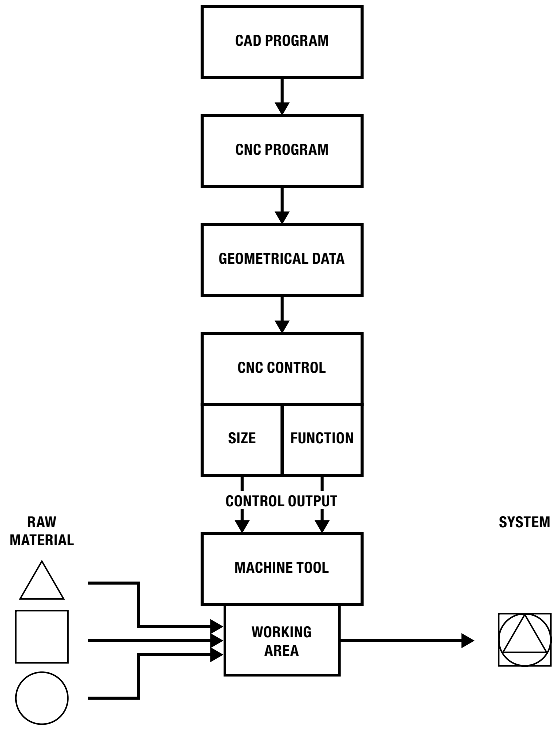
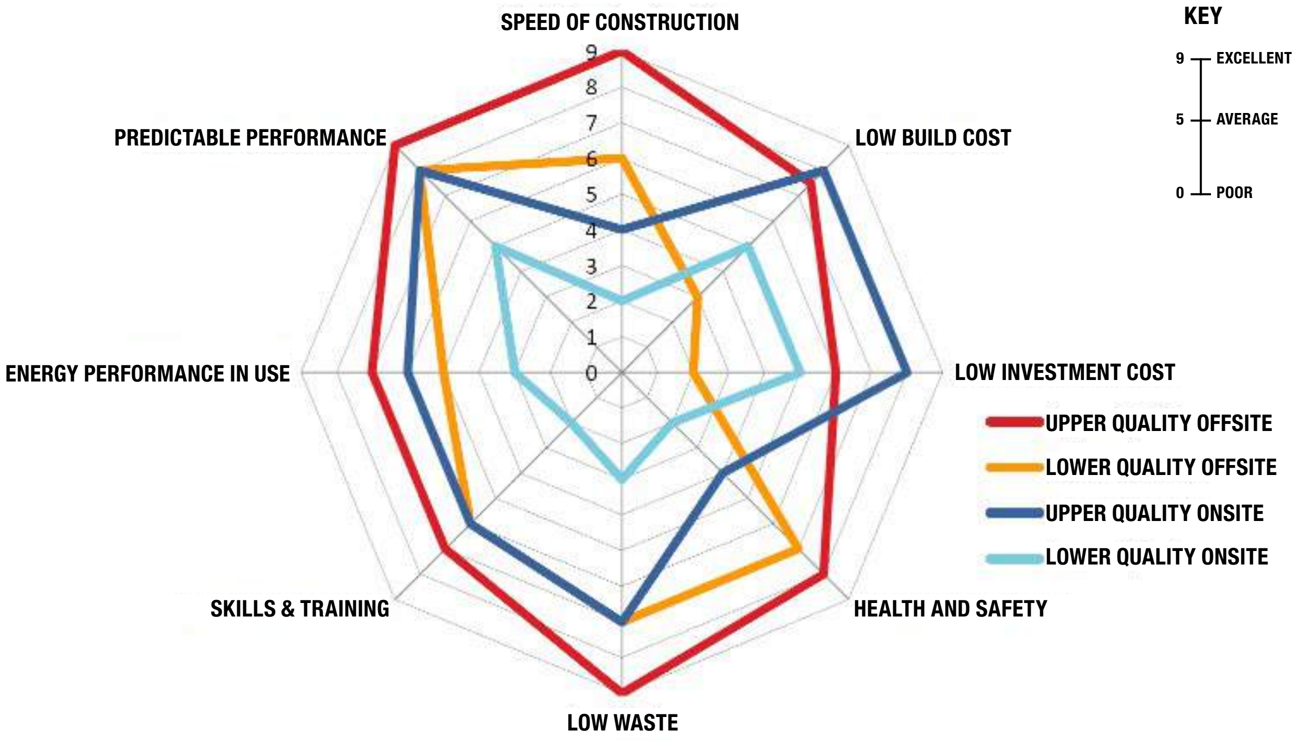


FIGURE 13 THE ROAD VEHICLES (CONSTRUCTION AND USE) REGULATIONS 1986

TABLE 5 OFFSITE DESIGN TERMINOLOGIES

TERM	DESCRIPTION
DESIGN FOR MANUFACTURE AND ASSEMBLY (DFMA)	DFMA is the concept of designing products and systems that are tailored for ease of manufacture, transport and assembly. It is therefore important to understand the supply chain components available, capabilities of the manufacturing process, logistical arrangements and any on-site restrictions.
STANDARDISATION	Standardisation is the extensive use of components, methods or processes in which there is regularity, repetition and a background of successful practice.
MASS CUSTOMISATION	Mass customisation is the fulfilment of customised requirements at an industrial scale utilising standardised components in order to achieve competitive prices and lead times.
OPTIMISATION	Optimisation is the process of maximising the impact of the beneficial variables whilst minimising the effect of the detrimental variables to create on balance the perfect end solution. An optimal sustainable solution should therefore achieve the correct balance between social, economic and environmental considerations in order to meet the requirements of the present without compromising the resources of future generations. From a technical design perspective an optimised solution should maximise thermal, acoustic and energy performance criteria without impinging upon cost (build and whole life cycle) giving due consideration to the manufacturing and assembly processes. Offsite therefore lends itself to optimisation given it requires a more holistic approach.
PRODUCT FAMILY ARCHITECTURE (PFA)	PFA is a range of standardised component parts used for a mass customised design approach often contained within a CAD library for design efficiency.

FIGURE 14 COMPARISON OF PERFORMANCE DRIVERS FOR A CONSIDERING HOUSES BUILT TO CONFORM TO BUILDING REGULATIONS PART L (ENGLAND AND WALES) (ADAPTED FROM CONSTRUCTION INDUSTRY COUNCIL – OFFSITE HOUSING REVIEW, FEB 2013)



IN READING THE DIAGRAM THE BIGGER THE SCORE THE BETTER THE QUALITY/ PERFORMANCE:

- **CONSTRUCTION TIME:** factory plus site time.
- **BUILD COST:** is factory plus site costs.
- **INVESTMENT COST:** attributable fixed and variable overhead e.g. factory, head office costs, prelims etc.
- **HEALTH AND SAFETY:** total project considering factory and site.
- **WASTE:** total waste from factory and site.
- **SKILLS AND TRAINING:** total attributable including design, factory, site, management etc.
- **ENERGY:** is the built product in whole life not including embodied energy.
- **PREDICTABLE PERFORMANCE:** time, defects, delivering to specification e.g. air pressure performance right first time.

TABLE 6 BUILDING STANDARDS - OBJECTIVES

TERM	OVERVIEW
STRUCTURE	To ensure that the structure of a building shall be designed and constructed in such a way that, during its intended life, it will not pose a threat to the safety of people in and around the building with an appropriate degree of reliability.
FIRE	To support preservation of life, assist the fire and rescue services and preservation of assets.
ENVIRONMENT	To ensure as is reasonably practicable, buildings do not pose a threat to the environment, and people in or around buildings, are not placed at risk as a result of: site conditions, hazardous and dangerous substances, the effects of moisture in various forms, an inadequate supply of air for human occupation of a building, inadequate drainage from a building and from paved surfaces around a building, inadequate and unsuitable sanitary facilities, inadequately constructed and installed combustion appliances, inadequately constructed and installed oil storage tanks.
SAFETY	To support the design of buildings that will ensure access and usability, reduce the risk of accident and unlawful entry.
NOISE	To limit the transmission of sound to a level that will not threaten the health of occupants from sound transmission emanating from attached buildings and a differently occupied part of the same building.
ENERGY	To support the conservation of fuel and power, in addition to limiting energy demand by addressing the performance of the building fabric and fixed building services.
SUSTAINABILITY	To support the process of sustainable development and the quality of 'sustainability' the built environment should account for: social, economic and environmental factors ; the potential for long-term maintenance of human well-being in and around buildings; the well-being of the natural world and the responsible use of natural resources, without destroying the ecological balance of the area where these resources originate or are processed and the ability for the built environment to be maintained.

For further information on the relevant regulatory requirement please see the following links:

- Scottish Government Technical handbooks: **LINK**
- England and Wales Approved documents: **LINK**

3.3 ENVIRONMENTAL IMPACT

The construction and use of buildings in the EU account for about half of all our extracted materials and energy consumption and about a third of our water consumption. The sector also generates about one third of all waste and is associated with environmental pressures that arise at different stages of a building's life-cycle including the manufacture of construction products, building construction, use, renovation and the management of building waste (European Commission, 2014). Therefore, in order to achieve sustainable developments via the use and application of offsite construction techniques it is important to understand that the specification of materials and the detailing of the system to be assembled will have an impact on the embodied carbon and operational energy usage (Table 6). Therefore, when considering the overall life cycle process (Figure 15) it is important to select materials appropriately and design the system in a manner that it can be delivered efficiently ideally using a localised supply chain.

> ***KEY POINT:*** *Forthcoming Resource Efficiency Directive from Europe (European Commission, 2014) will be a key opportunity for offsite construction systems to address the construction industry requirements for reduced waste, whole life cycle approach, future deconstruction, better integration of supply chains and improved quality control procedures.*

FIGURE 15 LIFE CYCLE PROCESS (MONAHAN ET AL, 2011)

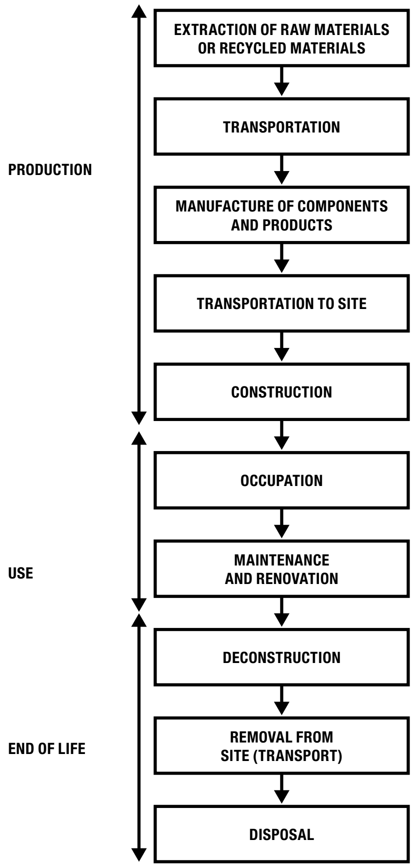


TABLE 7 SUSTAINABILITY AND ENVIRONMENTAL TERMINOLOGIES

TERM	EXPLANATION
SUSTAINABLE DEVELOPMENT	Sustainable development is concerned about ensuring a better quality of life for everyone both now and in the future and must therefore be capable of meeting the needs of the present without compromising the ability of future generations to meet their own needs. It includes three broad components: social, environmental and economic, often referred to as the ‘triple bottom line’. Sustainable development therefore requires multidisciplinary and interdisciplinary collaborations using both technical and humanistic approaches for the creation of sustainable communities resulting in a more sustainable society which addresses the following key issues: • Social progress that recognises the needs of everyone • Effective protection of the environment • Prudent use of natural resources • Maintenance of high and stable levels of economic growth and employment
SUSTAINABLE CONSTRUCTION	For construction to be sustainable, the basic ‘triple bottom line’ principles of sustainable development require to be incorporated. If this can be done, the construction process would be environmentally responsible, socially aware and be both economic and profitable.
LIFE CYCLE ANALYSIS (LCA)	Compilation and evaluation of all input and output flows and potential environmental impacts of a system throughout its lifecycle.
EMBODIED ENERGY	All the energy consumed in each lifecycle stage of a product or activity including that used in winning raw materials, the processing and manufacture of products, maintenance and repair and end of life disposal.
EMBODIED CARBON	Embodied carbon represents the carbon emissions (expressed as kg CO2 or kg CO2e) emitted as a result of primary energy use at each stage in a building’s lifetime.
OPERATIONAL ENERGY	Operational energy is the amount of energy consumed during the normal functioning of the building systems such as space and water heating, and lighting, and appliances.
LIFE CYCLE COST	Life cycle cost is the economic performance of a built system considering initial, operating and maintenance costs.

3.4 STRUCTURAL ROBUSTNESS AND BUILDING PERFORMANCE

For offsite to be part of a sustainable solution, design requires to be at the centre of a holistic process ensuring longevity through structural robustness and building performance (thermal and acoustic) given the impact that this can have on efficiency, user comfort and overall life cycle cost.

An offsite solution requires to be fully engineered for robustness taking into account the manufacturing and assembly processes as well as operational performance prerequisites such as durability and design life (Table 8). In addition, due consideration at the design stage is also required to consider the application of different loading configurations during logistical operations, tighter tolerances due to design freeze as well as system interfacing requirements.

The thermal properties of the building fabric play a major role in complying with carbon emission targets and this is reflected in the current building regulations with the thermal performance of a building, regarding its fabric and ventilation heat loss, generally described and analysed according to the thermal transmission of building components (U-value), the airtightness and thermal bridging of junctions (Table 9). In addition to thermal comfort the reduction in sound and noise transmission between attached properties is also an integral component to good quality of life for occupants. The effective sound insulation performance (Table 10) is a composition of the materials specification, the overall wall or floor system design and the interaction and critical junctions with external walls, windows and service zones.

TABLE 8 CONSIDERATIONS WHEN ENGINEERING FOR OFFSITE CONSTRUCTION (FIGURE 16)

CRITERIA	OVERVIEW	OFF-SITE DESIGN IMPLICATION EXAMPLES
DURABILITY	To ensure the overall durability of a system the engineer has a duty of care to ensure that architectural detailing is suitable and, where necessary, preservative or protective treatments are specified.	The integrity of "non-load bearing" items where fixings have safety implications should be considered such as the attachment of external cladding systems.
STANDARDISATION	As previous – see Table 5.	Standardisation of components or parts can result in a degree of over-specification that has to be balanced with overall efficiency gains in production and construction.
DESIGN LIFE	The design life of a system will vary depending on whether it is to be temporary or permanent. Over the duration of the design life the system must have adequate strength, stability and structural serviceability.	The structural adequacy of factory-produced systems and components has to be considered during the transportation and construction phases as the applied actions will in most cases be different from those experienced in service such as the lifting of wall assemblies or modules into location.
MOVEMENT	Failure to make provision for movement in the structural design of a system can cause serious serviceability problems such as excessive deformation or cracking of components.	Panelised systems and modules require to be designed and detailed with adequate levels of tolerance and allowance for movement giving due consideration to applied actions during transportation and assembly as well as interfacing with other assembled components which are in-situ for example pre-formed foundations.
STRUCTURAL ROBUSTNESS	A system is considered robust when the consequences of any applied action are not disproportionate to the cause. To provide additional robustness, redundancy can be introduced into the system via additional tying or specification of additional members in order that a redistribution of forces within the system can occur should an accident take place.	The system should be suitably structurally robust during the whole design life including for accidental actions, transportation and assembly such as the inclusion of additional members or tying in methods to provide alternative load paths. In this respect redundancy is an important consideration particularly in systems susceptible to progressive collapse such as panellised building; the loss of one component redistributes load or adds debris loading and leads to the sequential failure of other elements.
CONSTRUCTION (DESIGN AND MANAGEMENT)	The Construction (Design and Management) Regulations should be taken into consideration by the engineer to ensure the health, safety and welfare when undertaking construction projects.	Due consideration should be given to the sequence of operations during the assembly process in order that components can be interfaced and connected. Adequate provision should also be made where applicable for future access to allow routine maintenance and inspection to take place or decoupling for change of use.

KEY POINT (STRUCTURE): *Structural Eurocodes were implemented in April 2010 and over a period of harmonisation have been superseding British Standard Codes of Practice. The purpose of this pan-European approach to design is to reduce obstacles to trade, improve transparency of design and facilitate the specification and adoption of new engineered products.*

FIGURE 16 STRUCTURAL PERFORMANCE – APPLIED ACTIONS DURING LIFTING

TABLE 9 THERMAL ANALYSIS CRITERIA (FIGURE 17)

CRITERIA	OVERVIEW	OFF-SITE DESIGN IMPLICATION EXAMPLES
THERMAL TRANSMISSION (U-VALUE)	The flow rate of heat through and across a thickness of layered materials by given a difference of temperature at both sides. Materials with a high resistance to heat transfer are generally good materials for a low thermal transmission. Minimum values for domestic wall construction with current building regulations are 0.25 and 0.20 W/m2K for England & Wales and Scotland respectively.	The inclusion of thermal insulation into properties for off-site components would be the current boundary between simple and complex systems. Pre-fitted insulation further restricts site modification and places emphasis on design freeze stages. A more controlled installation process should improve the continuity of insulation and reduce corrections in the U-value due to air gaps according to ISO 6946:2007.
THERMAL BRIDGE	A thermal bridge is caused by a break in the insulation of the building fabric causing heat loss due to enhanced thermal conductivity between the internal and the external and can be found in three different scenarios: **1.** Repetition of a regular pattern i.e. studs in a timber frame wall; **2.** Inclusion of non-repetitive elements i.e. lintels; **3.** Junction of two different planes in the building i.e. corners.	Structural external panels require connection plates between consecutive elements, these can result in thermal bridging if not suitably detailed. This is compounded by weight restrictions for manual handling/lifting and logistics which often limit panel dimensions requiring additional junctions. It may also be necessary for these edge elements to be strengthened to accommodate aspects such as moving requirements.
AIR-TIGHTNESS	To reduce heat loss, any heated building should be designed to limit uncontrolled air infiltration through the building fabric. This is done by providing a continuous barrier that resists air movement through the insulation envelope and limits external air paths. Low air infiltration measured by air-tightness testing will contribute to energy performance but should not be so low as to adversely affect the health of occupants or the building fabric.	Whilst a greater level of installation quality can be maintained in an off-site environment, resulting in improved air tightness of component parts, panels and volumetric units often need to be connected on-site. Maneuverability and crane erect components require suitably trained installation teams to maintain integrity at these critical junctions. Nevertheless, service installations/penetrations often negate the need for such particular detailing, and such issues would normally only become apparent at very low levels of air tightness.

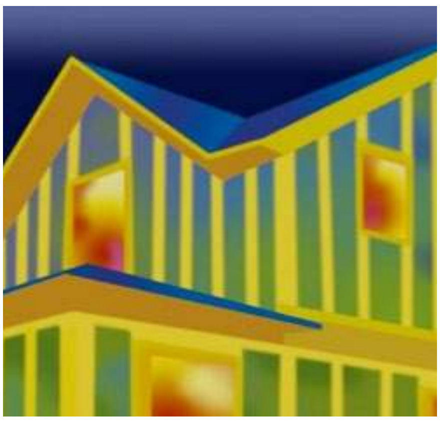
TABLE 9 CONTINUED ON THE NEXT PAGE

TABLE 9 THERMAL ANALYSIS CRITERIA (FIGURE 17)

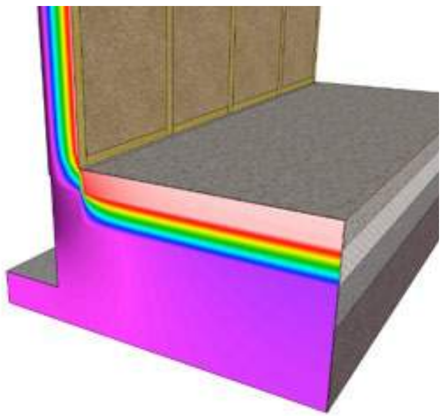
CRITERIA	OVERVIEW	OFF-SITE DESIGN IMPLICATION EXAMPLES
THERMAL MASS & THERMAL INERTIA	Materials that have a high inertia can absorb and store excess thermal energy when the buildings thermal load is high and release the energy when the load is low. Materials that are exposed directly to the sun, unlike most other building materials, are effective in absorbing and storing a great deal of the radiant energy. In order to be effective, a material must have a high heat capacity, a moderate conductance, high density, and a high emissivity.	Thermal mass and the transportation of off-site systems do not readily mix, requiring further on-site works to achieve this. The role of thermal mass in buildings has to be balanced with building use, and the need for a slow/fast thermal response.
HYGROSCOPICITY	Research has shown that hygroscopic building materials (materials that absorb a significant amount of moisture) can moderate indoor humidity conditions, which if too high can produce unacceptable indoor air quality conditions and if too low can bring respiratory illness and allergic reactions. Moisture transfer in hygroscopic materials has an effect on the whole heating and ventilation systems of buildings. Moderating the moisture and latent loads in buildings can reduce energy consumption. Natural materials like wood, fibre insulations and clay or lime renders can manage vapour transmission because of their high hygroscopicity.	With sufficient understanding of material properties and design, off-site practices should not limit performance in this regard.

KEY POINT (THERMAL): *The UK Climate Change Act became law in December 2008 and sets a legally binding target for a reduction in greenhouse gas emissions by 80% by 2050. The construction and occupation of buildings is a substantial contributor of global CO2 emissions, with almost a quarter of total global CO2 emissions attributable to energy use in buildings. Government policies and strategies to reduce the "performance gap" also provide opportunities for the offsite sector in terms of less standard deviation, addressing built-as-designed and better assurance towards the fabric performance (Zero Carbon HUB, 2014).*

FIGURE 17 THERMAL PERFORMANCE



A) IMAGE SHOWING THERMAL BRIDGE DUE TO NO THERMAL BREAK AND WALL STUDS



B) THERMAL IMAGE CONTOURS OF WALL SYSTEM WITH A THERMAL BREAK

TABLE 10 ACOUSTIC PERFORMANCE (FIGURE 18)

CRITERIA	OVERVIEW	OFF-SITE DESIGN IMPLICATION EXAMPLES
AIRBORNE SOUND INSULATION (SEPARATING TWO ATTACHED DWELLINGS)	This is the level of sound insulation provided by the separating wall or floor for attached houses and apartments. This is measured in decibels (dB) in the completed building and uses the ISO 717 criteria (DnT,w+Ctr) for England and Wales and (DnT,w) for Scotland and Northern Ireland. The higher the value the better the insulation against speech, television and normal living noise.	Lightweight building components rely on isolation and minimum connectors to provide sound insulation properties. This may restrict the movability of panels or connections used. Single wall panel systems although achieving the required airborne sound insulation may introduce issues with noise from horizontal impact transmission.
IMPACT SOUND TRANSMISSION (SEPARATING TWO ATTACHED DWELLINGS)	This is the level of sound transmission through a separating floor for apartments. This is measured in decibels (dB) in the completed building and uses the ISO 717 criteria (L'nT,w) across the UK. The lower the value the less sound is transmitted from footfall noise etc.	Incorporation of resilient ceiling or floor systems creates complex detailing interactions between elements. Some recent offsite floors can incorporate resilient systems installed at the manufacturing stage. A system design approach can assist in linking solutions for both airborne and impact sound transmission.
AIRBORNE SOUND INSULATION (SEPARATING TWO ROOMS IN THE SAME DWELLING)	This is the level of sound insulation provided by the internal wall or floor. This is measured in decibels (dB) and is a laboratory reported performance of the wall or floor using the ISO 717 criteria (Rw). The higher the value the better the insulation performance of the internal wall or floor.	Offsite manufactured systems for internal walls or floors used in laboratory testing can reduce laboratory workmanship variances as seen with built-in-lab for multi-component wall and floor systems. Using offsite systems for lab tests can improve the replicability and reduce variances in stated performance between different labs.
PRE-COMPLETION OR POST CONSTRUCTION TESTING (PCT)	This is the testing mechanism adopted in completed buildings and typically requires min 10% of the attached dwellings to be tested. In some cases if there are changes in the design and construction build-up of different separating walls or floors across the buildings in a site there should be at least 10% of each build type tested.	Off-site construction lends itself well to reduced standard deviations for onsite testing creating a tighter data cohort and better replicability.
ROBUST DETAILS	This is a process whereby if the new build construction designs adopted are registered via robust details then pre-completion testing is not required. Site managers are required to complete checklists of the works and the site may be visited by a Robust Detail Inspector to check the works and undertake a sample test. Robust Detail separating walls and floors which appear in the RD Handbook have already been tested and approved and are designed to have a mean performance of 5dB better than regulations to thus do not require pre-completion testing. Approximately 70% of all new housing is registered with robust details.	Many of the original generic Robust Details were developed utilising the common component parts now used within the off-site sector. Subsequent proprietary Robust Details indicate further potential for the incorporation of off-site systems into this scheme in future should sufficient testing be obtained on live sites. The status of having a Robust Detail wall or floor system is recognised across the UK and simplifies the specification and approvals process.

TABLE 10 CONTINUED ON THE NEXT PAGE

TABLE 10 ACOUSTIC PERFORMANCE (FIGURE 18)

CRITERIA	OVERVIEW	OFF-SITE DESIGN IMPLICATION EXAMPLES
DIRECT SOUND TRANSMISSION	This the sound or noise which transmits directly through the wall or floor (room to room)	As sound transmission involves both direct and indirect (flanking) pathways the use of offsite systems can improve the interaction and robustness at critical structural junction pathways. This also provides greater quality control and assists in maximising the attenuation of sound from the specified system and helps avoid product substitution on sites.
FLANKING SOUND TRANSMISSION	This is the sound or noise which travels indirectly e.g. via perimeter external walls. In a typical test of a separating floor in an apartment there will be 1 direct path through the floor and 12 indirect or flanking paths via perimeter walls.	

KEY POINT (ACOUSTIC): *The diversity of sound insulation performance standards and requirements across the UK can lead to a variation on a construction wall or floor system to achieve each target. Offsite construction can provide better control on the specific system solutions and thus reduce variation and standard deviation. Future ISO / CEN acoustic classification schemes for separating walls and floors provides an opportunity for offsite systems to be able to target set levels and classifications with improved quality and reliability. Offsite systems that develop to become robust details compliant have an opportunity to enter several markets and be recognised for the enhanced performance, robustness and better replicability that offsite offers.*

FIGURE 18 ACCOUSTIC PERFORMANCE – SEPARATING WALL AND FLOOR JUNCTION DETAILED FOR ACOUSTIC SEPARATION

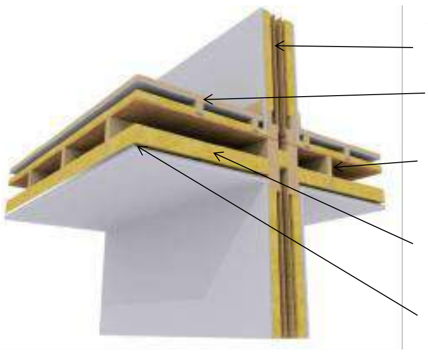


TABLE 10 OFFSITE MANAGEMENT TERMINOLOGIES

TERM	OVERVIEW
BUILDABILITY	The ease and efficiency by which assemblies and sub-assemblies can be brought together, connected and made to function as intended.
JUST IN TIME	Corresponds to zero time between programme events which are sequential and rely upon each other. By implementing just in time principles the overall critical path (sequence of events that are most critical to programme completion) can be reduced resulting in an earlier completion/handover date.
SLIPPAGE	An elongation of the programme caused by unpredicted delay.

3.5 MANAGING THE OFFSITE PROCESS

The skills, knowledge and behaviours of offsite construction are different from those of traditional on-site construction and the move to a factory environment results in increased levels of lean production philosophy and automation. In order to realise the benefits this brings with respect to environmental impact, whole life cycle cost and health and safety strategic planning and logistical optimisation needs to be implemented through coherent management of the different phases of activity:

CLIENT AND CUSTOMER MANAGEMENT
For offsite to achieve its full potential in terms of overall customer or client satisfaction it is important to engage the offsite system provider as early in the project process as possible, ideally at project inception. Early engagement facilitates a strong project partnership which therefore matches the capabilities of the offsite provider with the expectations of the customer to ensure a high level of value is ascertained from the project (Figure 19).

DESIGN MANAGEMENT
Information flow between the architect, designers, production facility and on-site teams requires to be closely integrated with agreed responsibilities for information management and sign off. All those within the process require to have an understanding, and accept as reasonable, the tolerance that each party is working without impinging upon overall efficiency and quality. Interfacing is critical and as a result detailed design requires to be completed early and frozen prior to the commencement of manufacturing to ensure on-site assembly tolerances are met.

PROGRAMME MANAGEMENT
A programme of activities is essential before manufacturing begins. The programme should be mapped to that of the overall programme of works and should additionally include:

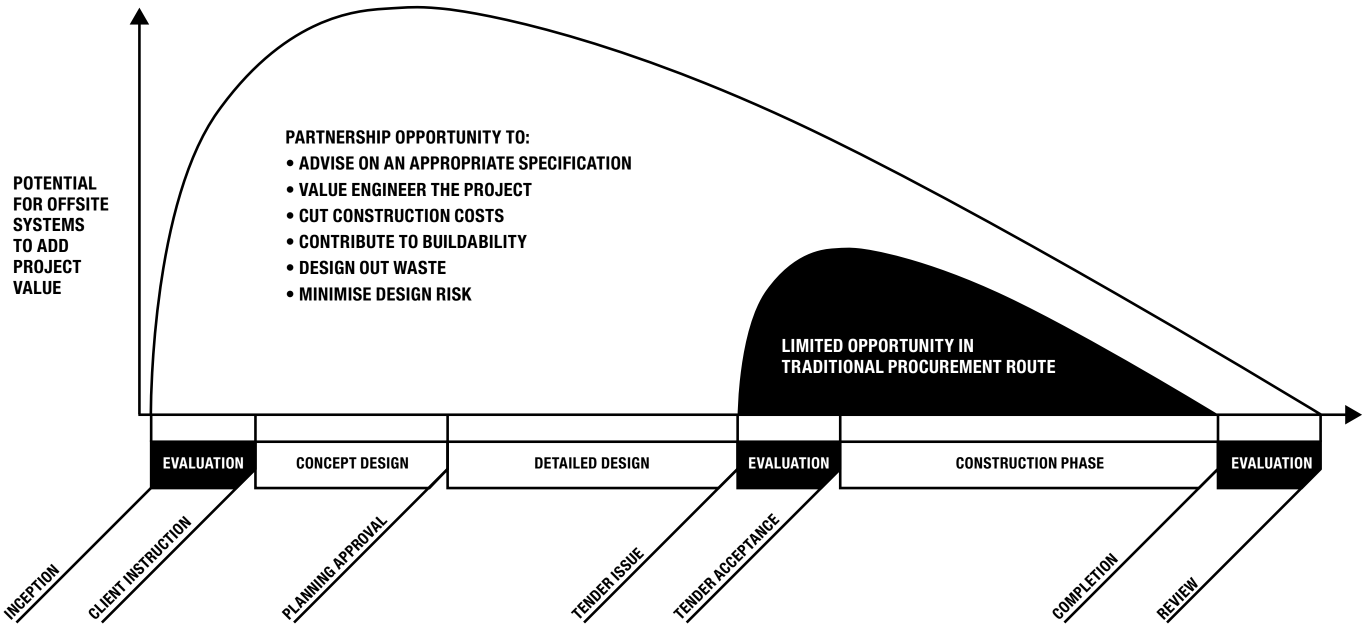
- Design freeze date;
- Period of notice required by the manufacturer to check that tolerances on-site are within agreed limits;
- The timetable for delivery of offsite assemblies;
- A period and procedure for checking the units before accepting handover;
- Period for latent defects liability.

Within the programme a degree of accountability for any slippage (Table 10) should be agreed for instances such as late delivery of assemblies or delays imposed on the manufacturer (e.g. if the site is behind schedule and not able to accept delivery at the agreed time).

TRANSPORTATION AND LOGISTICS PLANNING
To realise the full efficiency savings of offsite 'just-in-time' delivery of the manufactured assemblies should be implemented. Storage of pre-assembled components or units on-site before erection is inefficient and may not be practical due to site constraints (e.g. lack of space) and weather conditions (can result in damage to internal linings for example). Delivery timetables should be agreed in advance and monitored relative to programme progress and communicated to the factory and haulage company. Other considerations include the context of each site:

- Alternative transport methods e.g. railway and rivers, (where appropriate);
- Local constraints and consequent route planning e.g. speed, height and width restrictions (bridges and overhead obstructions);
- Lifting operations plan and the siting if required of a crane relative to its associated reach capacity.

FIGURE 19 OFFSITE VS TRADITIONAL PROJECT MANAGEMENT PROCESS (ADAPTED FROM STEWART MILNE TIMBER SYSTEMS)

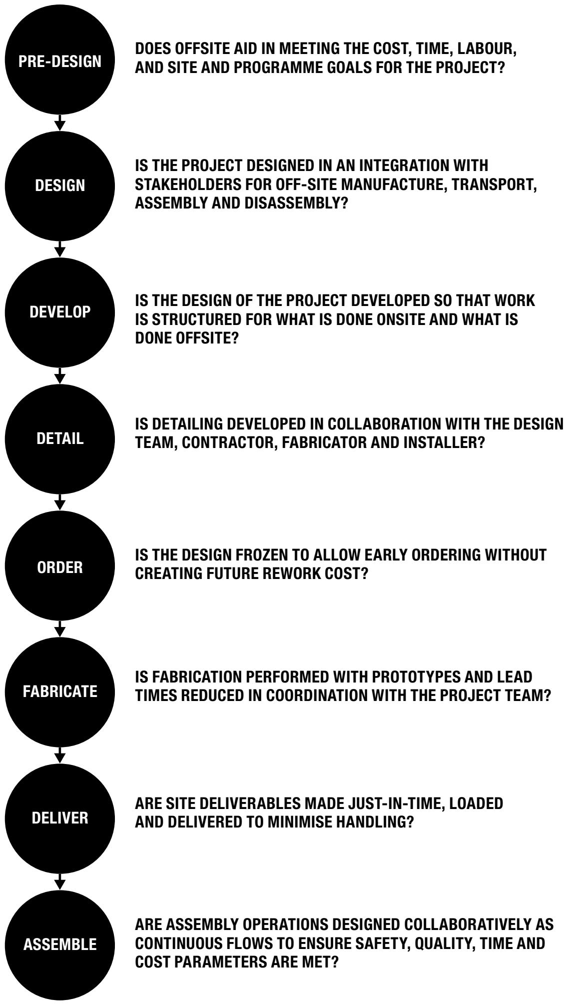


KEY POINT: *The accident rates in manufacturing are some 29% less for major injuries and 52% less for fatalities. Therefore, moving construction activities to a factory environment should correspond to a significant reduction in the number of major injuries and fatalities which are recorded each year (Krug, et al, 2013).*

04

SUMMARY

FIGURE 20 TEAM COLLABORATION QUESTIONS FOR A SUCCESSFUL OFFSITE PROJECT (ADAPTED FROM THE INTEGRATED TECHNOLOGY IN ARCHITECTURE CENTER AT THE UNIVERSITY OF UTAH'S COLLEGE OF ARCHITECTURE AND PLANNING)



Internationally there is momentum to build more offsite and it has been identified by the UK Government as a vehicle for the delivery of a more sustainable built environment. Within the UK there are regional hubs of offsite expertise and activity with Scotland for example recognised as a major hub for timber offsite systems with an emphasis on house-building (see case study examples).

This document serves as an introduction to Building Offsite and you should now understand what it is, why it is advantageous and why also there are barriers to its up take. You should have a better understanding of how offsite can be applied to a project if techniques such as Design for Manufacture and Assembly (DFMA) are employed, how to create more sustainable outputs from its adoption and also an understanding of how to manage the process.

Overall you should now understand that building offsite is a change in construction culture towards a process of continuous improvement with enhanced productivity and as a result it requires to be underpinned with research, innovation and training. The skills required to move building to an offsite environment are therefore required at all levels of the operation from finance to assembly, from design to manufacture and from operation to decommission. Given the above stakeholder collaboration and team work is key to the success of offsite construction (Figure 20).

05

CASE STUDIES: VOLUME PRODUCTION OF LOW CARBON AFFORDABLE HOMES

(THE HOW OF OFFSITE CONSTRUCTION)

5.1 CASE STUDY 1

CCG (OSM) FACTORY FACILITY – THE COMMONWEALTH GAMES ATHLETES VILLAGE

DESCRIPTION

The Athletes' Village, situated in Dalmarnock at the heart of the Clyde Gateway urban redevelopment programme, represents a £150 million investment and is the most significant housing led regeneration initiative in the UK.

Delivered by the City Legacy Consortium – consisting of CCG, Cruden, Mactaggart & Mickel and WH Malcolm – the 88 acre site was developed to provide accommodation for 6,500 athletes and officials during the 2014 Commonwealth Games.

The Village is now a lasting legacy providing sustainable mixed-tenure housing, all set alongside a world-class sports amenity and planned within public open spaces. Of the 700 homes built by the consortium, 400 are social housing rental units and 300 are for private sale. A range of 12 property types are available from one-bedroom apartments to four-bedroom detached houses. These contemporary, spacious and stylish homes will help reverse the decline of the area by creating a safe community environment, offering tenants and owners, a range of affordable homes.

PROJECT NAME
The Athletes' Village

DATE COMPLETED
July 2014 (Games mode)
March 2015 (occupancy)

BUILDING TYPE
Private and social housing

LOCATION
Dalmarnock, Glasgow

ARCHITECT
RMJM

CLIENT
City Legacy Homes

CONTRACTOR
CCG (Scotland) Ltd

OFFSITE COMPONENT PROVIDER
CCG (Scotland) Ltd

PROJECT SIZE /M2
700 Units – (237 Nr CCG Element)

TOTAL BUILD COST
£28 Million (CCG element)

OFFSITE METHODS
Closed panel / floor cassettes / roof cassettes

PROCESS
For the CCG element, the following offsite construction was used:

- Enhanced closed panel walls; u-value 0.15; Thermally broken studs
- Floor cassettes
- Roof cassettes panels; u-Value 0.12
- Air tightness = Less than 3.0
- Contract period = 22 months
- As result of using Offsite construction = 14 months
- Design took cognizance for games and legacy mode at the original design stage
- Original design of the majority of the units was based on a range of house types developed by CCG which took cognizance of design for manufacture principles
- Guaranteed Maximum Price contract
- M & E containment factory installed
- MVHR ductwork within floor cassettes factory installed

INFORMATION AND TOOLS
Software modelling used was CCG's own timber frame design software, HsbCAD which has 3D functionality to assist with design drawings.

BUILDING PRODUCTS AND SYSTEMS
A project of this scale needs careful onsite management; this was achieved by maximising the benefits of Modern Methods of Construction (MMC) combined with Offsite Building technology which delivers onsite efficiencies such as rapid site installation and less onsite waste as well as unsurpassed environmental credentials and quality control, as structural components are manufactured in factory conditions to exacting standards.

CCG utilised their own Off Site Manufacturing (OSM) facility based in Cambuslang to build their allocation of 237 homes and the CHP Energy Centre. Given that the project had a completely inflexible start date, it was imperative that the construction process was delivered on time. CCG's offsite efficiency helped reduce the pressures of such a stringent deadline and the build allocation was completed in a remarkably short period of 14 months – a typical terrace of townhouses was erected and wind and water tight in 10 days.

Each individual home in the Athletes' Village had to meet an external wall U-value requirement of 0.15 W/m2K which was met via using a fully closed composition with a thermally broken ITW Spacestud. The advanced structural timber system had factory fitted timber windows, doors and pre-installed insulation, all contributing to a reduction in carbon emissions and providing cost savings as energy consumption is vastly reduced. Clear span engineered floor cassettes were also installed to create open-plan living arrangements and flexible living space.

Buildings through fabric and PV panels achieved 60% carbon reduction. Add on the contribution of CHP, all properties achieve 100% carbon reduction.

RESULTS

The highly efficient design has led to the development being awarded an Ecohomes 'Excellent' rating, and a BREEAM 'Excellent' rating for the care home. Energy efficiency is enhanced further by innovative design features including high quality thermal insulation, double-glazing, solar PV panels together with an Air Permeability Rate 3 m3/h.m2@50Pa, significantly reducing energy costs.

One of the greatest highlights of the project was the ability for the consortium members to operate in synergy. City Legacy's strong partnership delivered a project on time and on budget that has been met with unprecedented demand for homes. During the sales launch period, 238 of the 242 homes released were reserved in a two month period, clearly demonstrating the phenomenal demand for these unique homes. One third of these buyers came from the immediate location with the remaining from the Greater Glasgow area. First time buyers accounted for half of the number of sales, assisted by the Help to Buy (Scotland) Scheme. This was a key target group in our original objectives.

BUILD METHODS	Offsite timber frame
MATERIALS USED	Timber frame Insulation – Mineral wool – 0.32 thermal density
NO. OF UNITS IN DEVELOPMENT	237
U- VALUES	Walls- 0.15W/m2 Roof - 0.12
DESIGN DURATION	6 months
CONSTRUCTION DURATION	14 months
FACTORY TIME	10 months
ERECTION TIME	10 months

CCG OSM LTD. COMPANY OVERVIEW

CONTACT INFO (EMAIL, WEB AND GENERIC TELEPHONE)	searlie@ccgosm.co.uk www.c-c-g.co.uk/divisions/site-manufacturing 0141 641 9430
FOUNDED	2007
SHORT OVERVIEW DESCRIBING COMPANY AND ETHOS	CCG OSM is a purpose built centre of manufacturing excellence creating high quality low carbon buildings. Following a lengthy period of extensive market research across the globe to determine best practices in Modern Methods of Construction, we invested £12m to develop our state of the art Offsite Manufacturing facility – OSM – a truly innovative and unique production hub. Factory controlled conditions and precision engineering guarantee quality, with greater tolerances, determined by fewer panels, junctions and thermal bridges ensuring better air tightness and improved efficiency. In addition to this, our offsite system creates onsite efficiencies such as rapid site erection, protection from adverse weather conditions and fewer wet trade interfaces. For the true benefits of Offsite Manufacture to be fully realised by the customer, we at CCG OSM recognize that successful project delivery requires the integration of both the offsite and onsite process at an early stage of the build process. Through research and first-hand experience, we have acquired a proven track record in designing and implementing innovative products within our customers build requirements.
LOCATION(S)	2 Drumhead Road, Glasgow East Investment Park, Glasgow G32 8EX
NUMBER OF EMPLOYEES	110
ANNUAL TURNOVER	2014/2015: Turnover £14.0m (projected)
NUMBER OF UNITS (EQUIVALENT TO 100M² HOUSE)	Capability of up to 3000 units per annum
MARKETS (PRIVATE HOUSE BUILDER, SOCIAL AFFORDABLE ETC?)	Private house builder, Social housing, Schools, Student accommodation, Offices, Leisure
TYPE OF SYSTEM AND ANY UNIQUE SELLING POINTS	Customers are offered full flexibility in the specification of components. The iQ System comprises enhanced wall, floor & roof cassette panels. Our clients are given the opportunity to choose from each stage of the process to meet any level of requirement. • Stage 1: Open Panel: Long panel frame / OSB / BM / Windows and Doors • Stage 2: Standard “Enhanced” Panel: Insulation / Thermal Closing Layers / Vapour Control / Air Tightness Layer / Service Zone • Stage 3: Serviced “Enhanced” Panel: Electric / Plumbing / Vent Services / Dry Lining Board • Stage 4: Full Closed Panel: External Lightweight Claddings

5.2 CASE STUDY 2

STEWART MILNE TIMBER SYSTEMS – THE SERPENTINE

DESCRIPTION
In June 2012, Thames Valley Housing (TVH) welcomed the new residents to The Serpentine, its flagship affordable housing development in Aylesbury. Thames Valley Housing is a registered social landlord which provides affordable rented homes, shared ownership, market rent and accommodation for students and key workers in the south east of England.

From the outset, TVH was determined that The Serpentine would combine quality and contemporary design in an attractive, landscaped setting. The building divides the site into two clear zones: the 'street side' extends from the main entrance to the site and incorporates a child-friendly Home Zone, while the 'garden side' offers private green spaces for a range of the new homes and faces onto the residential area to the east.

PROJECT NAME
The Serpentine

DATE COMPLETED
June 2012

BUILDING TYPE
Affordable Housing

LOCATION
Aylesbury

ARCHITECT
Make Architects

CLIENT
Thames Valley Housing

CONTRACTOR
Denne Construction

OFFSITE COMPONENT PROVIDER
Stewart Milne Timber Systems

PROJECT SIZE /M2
98 Homes

OFFSITE METHODS
Sigma II Closed panel timber system

PROCESS

The project adopted the Stewart Milne Timber Systems Sigma II Build System. The site was very constrained off a main artery road, so the use of offsite construction helped reduce traffic movement and disruption. The build program was very fast, as the building is effectively one long S-shape, working its way from the back to front of the site, so speed was important. To do this the contractor selected a Sigma II closed panel, with pre-fitted windows, floor cassettes and ceiling cassettes, so the building was made secure and weather tight very quickly. The rate of build was to complete 4 homes per week, over approximately a 20 week period.

INFORMATION AND TOOLS

Due to the s-shape design there was a lot of upfront early engagement on the development of the design with the architect. Each home is facetted, and a solution to floor plate design evolved, which ensured that each unit had at least two 90 degree angles to work from. This made the floor cassette and roof designs more standard, with significantly less shaped infills. The use of 3D modelling helped to set out the roof geometry and floor setting out, which was critical to achieving accurate dimensional setting out on site.

BUILDING PRODUCTS AND SYSTEMS

Stewart Milne Timber Systems, the UK's leading provider of timber system building solutions, played a crucial role in this innovative project, from the initial design through to the supply and erection of the closed panel timber build system. The success of this unusual design showcases both the flexibility and cost effectiveness of building with timber as well as the market leading expertise of Stewart Milne Timber Systems' technical team.

TVH was committed to using innovative materials and building methods to meet the highest standards of energy efficiency and sustainable living, while also challenging the architects to deliver a design with a very low build cost of less than £60,000 per home. Plus, with the housing association keen to hand over the keys to the new tenants, speed of build was a crucial driver.

The technical and design teams identified design and structural solutions which enabled them to meet the brief while keeping costs under control. For example, the whole building is segmental, with straight walls, and in each house type all internal walls are set at right angles to one of the party walls. That allowed Stewart Milne Timber Systems to manufacture all of the floor and ceiling cassettes in the factory on fully automated lines.

RESULTS
With the above considerations in mind, Stewart Milne Timber Systems' high specification Sigma II Build System was an ideal fit for the project and helped to turn TVH's bold vision into reality on a limited budget. The end result is a sustainable development of highly liveable homes featuring energy efficient U-Values of 0.15 W/m2K in the external walls, 0.15 W/m2K in the ceilings (pre-insulated cassettes), and 1.4 W/m2K windows, pre-fitted to the external walls.

Offsite manufacture and construction of the build system also delivered a further range of benefits for the client and future tenants that include: a factory quality product, produced and erected more efficiently, with few defects; greater air-tightness and better insulation which will result in lower energy costs in the future and help meet targets for sustainability; and a safer site throughout the construction period thanks to reduced manual handling.

LESSONS LEARNED
Sigma II has become a system of choice for many projects. This project showed the flexibility that can be achieved, whilst responding to the site constraints to deliver a very unique building in half the time of traditional construction. The learning gained from this project has allowed SMTS to refine the system and use it on many other projects, where sustainability, good design and speed are important considerations.

BUILD METHODS	Sigma II Closed panel timber build system- pre insulated and windows pre fitted, with floor and roof to cassettes, all factory manufactured.
MATERIALS USED	Timber- closed panel system 100% Timber cladding externally. Zinc standing seamed roofing systems Beam and block floors, with insulated screed overlay.
NO. OF UNITS IN DEVELOPMENT	94
U- VALUES	0.15 W/m2K in the external walls, 0.15 W/m2K in the ceilings (pre-insulated cassettes), 1.4 W/m2K windows, pre-fitted to the external walls
DESIGN DURATION	24 weeks lead in
CONSTRUCTION DURATION	11 months
ERECTION TIME	20 weeks

STEWART MILNE TIMBER SYSTEMS COMPANY OVERVIEW

CONTACT INFO (EMAIL, WEB AND GENERIC TELEPHONE)	info@stewartmilne.com www.stewartmilne.com Tel: 01224 747 000
FOUNDED	1975
SHORT OVERVIEW DESCRIBING COMPANY AND ETHOS	SMTS are one of the largest manufacturers and installers of timber frame buildings in the UK, we pride ourselves on a customer centric approach, quality and expertise, delivered through committed team players, in partnership with our customers.
LOCATION(S)	Office locations in Aberdeen, Glasgow, Manchester and Witney Oxfordshire, with production plants in Aberdeen and Witney.
NUMBER OF EMPLOYEES	Approximately 230
ANNUAL TURNOVER	Circa £45m to Y/E 2014
NUMBER OF UNITS (EQUIVALENT TO 100M^2 HOUSE)	Approximately 4,500 per year with capacity for circa 10,000.
MARKETS (PRIVATE HOUSE BUILDER, SOCIAL AFFORDABLE ETC?)	Operating in private and social housing sectors, bed-space accommodation for hotels, leisure and student living, along with selected healthcare projects.
TYPE OF SYSTEM AND ANY UNIQUE SELLING POINTS	We offer our Sigma OP Range of open panel solutions and the triple award winning Sigma II Build System, closed panel timber frame solution, with the option of prefabricated floor and rafter cassettes, roof elements and factor fitted windows/doors. Our Sigma II Build System is the only BBA certified and BOPAS accredited closed panel system on the market. We offer unrivalled technical expertise and project management, giving surety of project delivery to our customers.

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ADDITIONAL INFORMATION

This section contains:

- Table 7.1
  Additional open source publications
- Table 7.2
  Other useful UK organisations
- Table 7.3
  Other useful on-line resources

TABLE 7.1 ADDITIONAL OPEN SOURCE PUBLICATIONS

TOPIC	TITLE	YEAR	OVERVIEW	LINK
BIM	NBS National BIM Report	2014	Annual National Building Specification report on the UK implementation of Building Information Modelling.	**LINK**
BUILDING PERFORMANCE	Closing the gap between design and as-built performance – end of term report	2014	Report that draws together the findings of the Zero Carbon Hub project on Closing the Gap Between Design and As-Built Performance.	**LINK**
SKILLS	No more lost generations – Creating construction jobs for you people	2014	A report on the cross-party parliamentarians' enquiry in how to make better use of the UK construction programme for the training and employment of young people in the industry; and to find ways to ensure investment in the sector leaves a lasting legacy for communities and creates a sustainable, better-skilled industry.	**LINK**

TOPIC	TITLE	YEAR	OVERVIEW	LINK
ENVIRONMENTAL	Resource efficiency opportunities in the building sector	2014	An initiative to promote a more efficient use of resources consumed by new and renovated commercial, residential and public buildings and to reduce their overall environmental impacts throughout the full life cycle.	**LINK**
ENVIRONMENTAL	Housing Innovation Showcase: Energy Demand – First year of occupation	2014	Report of the Housing Innovation Showcase (HIS), developed by Kingdom Housing Association (KHA) analysing the energy use derived from a combination of heat and electricity consumption and comparing it with typical household figures and average regional figures whilst observing total carbon and cost comparisons across the development.	**LINK**
STRATEGY/POLICY	Building for The Future – The Scottish Construction Industry's Strategy 2013-2016	2012	The Construction Scotland Strategy document which sets out the ambition and priorities for the period of 2013 to 2016.	**LINK**
SKILLS	Technology and skills in the Construction Industry – Evidence Report 74	2013	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.	**LINK**
STRATEGY/POLICY	Construction 2025	2013	A UK Government report which outlines a clear and defined set of aspirations for the construction industry in order that it be at the heart of a low carbon, resource efficient, modern and globally competitive economy. The three strategic priorities set out be the report are as follows: • Smart construction and digital design • Low carbon and sustainable construction • Improved trade performance	**LINK**
INNOVATION	Building Sustainable Homes at Speed	2013	This research review gives a series of case studies of selected sustainable housing developments which had the potential to achieve significant gains in construction speed by using innovative approaches. It summarises the risks that house builders, registered providers, manufacturers and design teams should be aware of when considering how to build sustainable homes quickly, highlights the risks that are of most concern and suggests how the most significant risks can be avoided or mitigated.	**LINK**

TOPIC	TITLE	YEAR	OVERVIEW	LINK
STRATEGY/POLICY	Review of Scottish Public Sector Procurement in Construction	2013	A review of the entire public sector and affordable housing sector construction procurement arrangements in Scotland which makes recommendations to support improvements in efficiency, delivery and sustainability of construction procurement projects across the Scottish public sector.	**LINK**
STRATEGY/POLICY	Scotland's Sustainable Housing Strategy	2013	The Sustainable Housing Strategy sets out the Scottish Governments vision for warm, high quality, affordable, low carbon homes and a housing sector that helps to establish a successful low carbon economy across Scotland.	**LINK**
STRATEGY/POLICY	Creating Places - A policy statement on architecture and place for Scotland	2013	Scotland's new policy statement on architecture and place sets out the comprehensive value good design can deliver. Successful places can unlock opportunities, build vibrant communities and contribute to a flourishing economy. The document contains an action plan that sets out the work that will be taken forward to achieve positive change.	**LINK**
MARKET SECTOR	Offsite Housing Review	2013	A review of the housing market in England with an examination into the potential for offsite construction methods to play a more significant role in the housebuilding for the Department for Communities and Local Government and the Department for Business, Innovation and Skills.	**LINK**
SUSTAINABILITY	Offsite Construction: Sustainability Characteristics	2013	A report examining the credentials of offsite construction within the context of a definition of sustainability.	**LINK**
MARKET SECTOR	Strategic Review of the Offsite Construction Sector in Scotland	2013	A study undertaken to evaluate the Scottish Offsite construction sector via direct input from small, medium and large scale offsite construction manufacturers as well as large scale supply chain companies, research and development based companies and offsite developer clients where all works are subcontracted.	**LINK**

TOPIC	TITLE	YEAR	OVERVIEW	LINK
STRATEGY/POLICY	Offsite Production and Manufacturing – Research Roadmap Report	2013	A report on recent developments in research and practice on New Production and Business Models in Construction highlighting the impact of new production models in the Architecture, Engineering and Construction (AEC) industries with findings from both a developed and developing world perspective.	**LINK**
INFORMATION	Buildoffsite Glossary of Terms	2013	A glossary of terms to be used to define the catergories and subcategories of offsite construction.	**LINK**
STRATEGY/POLICY	Homes that don't cost the earth – A consultation on Scotland's Sustainable Housing Strategy	2012	The Sustainable Housing Strategy sets out a vision for warm, high quality, affordable, low carbon homes and a housing sector that helps to establish a successful low carbon economy across Scotland.	**LINK**
STRATEGY/POLICY	Building Information Modelling – Industrial strategy: government and industry in partnership	2012	Capability assessment setting out the actions that government and industry will take to create opportunities for the UK construction sector by becoming a world leader in building information modelling (BIM).	**LINK**
INNOVATION/ RESEARCH	Open Building Manufacturing – key technologies, applications and industrial cases	2009	ManuBuild - "Open Building Manufacturing", is an industry-led collaborative research project on Industrialised Construction, part-funded by the European Commission. The ManuBuild vision is of a future where customers will be able to purchase high quality, manufactured buildings having a high degree of design flexibility and at low cost compared to today. For the first time, inspirational unconstrained building design will be combined with highly efficient industrialised production.	**LINK**
ENVIRONMENTAL	Waste Minimisation through Offsite Timber Frame	2008	A case study demonstrating the positive impacts of utilising modern production lines for the manufacture of offsite timber systems.	**LINK**
MARKET SECTOR	Perspective of UK house builders on the use of offsite modern methods of construction	2007	An investigation of the UK housebuilders' views on the use of offsite Modern Methods of Construction by Loughborough University.	**LINK**

TOPIC	TITLE	YEAR	OVERVIEW	LINK
STRATEGY/POLICY	Modern Methods of Construction	2006	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.	**LINK**
STRATEGY/POLICY	Offsite Modern Methods of Construction in Housebuilding – perspectives and practices of leading UK housebuilders	2005	A study on the applications of innovative building technologies in housing construction.	**LINK**
STRATEGY/POLICY	Using modern methods of construction to build homes more quickly and efficiently	2005	An independent examination on behalf of the Office of the Deputy Prime Minister and the Housing Corporation to identify how to get best value when using modern methods of construction. The aim is to provide practical help to Registered Social Landlords and private developers.	**LINK**
STRATEGY/POLICY	Current Practice and Potential Uses of Prefabrication	2001	A desk study of prefabrication in the UK to give context to the use of prefabrication techniques.	**LINK**
STRATEGY/POLICY	Rethinking Construction – The Report of the Construction Task Force	1998	The report of the Construction Task Force to the Deputy Prime Minister, John Prescott, on the scope for improving the quality and efficiency of UK construction.	**LINK**

TABLE 7.2 OTHER USEFUL UK ORGANISATIONS

SOURCE	OVERVIEW	HOST WEBSITE
BUILDING INFORMATION MODELLING (BIM) TASK GROUP	The Building Information Modelling (BIM) Task Group are supporting and helping deliver the objectives of the Government Construction Strategy and the requirement to strengthen the public sector's capability in BIM implementation with the aim that all central government departments will be adopting, as a minimum, collaborative Level 2 BIM by 2016.	**LINK**
BUILDOFFSITE	BuildOffsite is an industry-wide campaigning organisation that promotes greater uptake of offsite techniques by UK construction. Buildoffsite is an alliance of clients, developers, designers, contractors, manufacturers, suppliers, government, advisors and researchers.	**LINK**
BUILDOFFSITE PROPERTY ASSURANCE SCHEME (BOPAS)	BOPAS has been jointly developed by Buildoffsite, The Royal Institution of Chartered Surveyors (RICS), Lloyd's Register and Building LifePlans Ltd (BLP), in consultation with the Council of Mortgage Lenders (CML) and the Building Societies Association (BSA), to provide assurance to the lending community that innovatively constructed properties against which they may be lending, will be sufficiently durable as to be readily saleable for a minimum of 60 years.	**LINK**
NATIONAL BUILDING SPECIFICATION (NBS)	NBS provide specification information solutions to the construction industry.	**LINK**
MODULAR BUILDING INSTITUTE (MBI)	The Modular Building Institute (MBI) is the international non-profit trade association serving modular construction. Members are manufacturers, contractors, and dealers in two distinct segments of the industry - permanent modular construction (PMC) and relocatable buildings (RB). Associate members are companies supplying building components, services, and financing.	**LINK**
STRUCTURAL TIMBER ASSOCIATION (STA)	STA represent a membership base of businesses and people involved in construction using engineered timber.	**LINK**
TRUSSED RAFTER ASSOCIATION (TRA)	The TRA is a recognised source of specialist information about trussed rafters for specifiers, contractors and end users.	**LINK**
TIMBER TRADES FEDERATION (TTF)	The TTF are a membership group representing the UK's timber industry.	**LINK**

SOURCE	OVERVIEW	HOST WEBSITE
NATIONAL HOUSING BUILDING COUNCIL	NHBC is a standard-setting body and provide of warranty and insurance for new homes.	**LINK**
WOOD FOR GOOD	Wood for good is the UK's wood promotion campaign. The Wood for Good campaign works on behalf of the whole timber industry in the UK. It aims to promote the suitability and sustainability of wood as a building material to the construction and logistics sectors and associated professionals such as architects and design engineers.	**LINK**
BUILDING RESEARCH ESTABLISHMENT (BRE)	BRE operates as an independent and impartial research based consultancy, testing and training organisation which looks to offer expertise in all aspects of the built environment and associated industries. BRE is based in Watford but also has offices in Scotland, Wales and Ireland. BRE has also developed an international outreach strategy through the development of a series of global innovation parks.	**LINK**
TIMBER RESEARCH AND DEVELOPMENT AGENCY (TRADA)	TRADA is a not for profit membership organisation. TRADA's aim is to provide information on timber and wood products in order to promote the use of the material. It does this through ongoing programs of information programs, research, publications and training courses. BM TRADA is the testing, inspection and certification arm of the organisation providing research and information programs as well as the administration of its membership services. Based in High Wycombe, TRADA serves the UK.	**LINK**
THE INTEGRATED TECHNOLOGY IN ARCHITECTURE CENTER (ITAC)	The Integrated Technology in Architecture Center at the University of Utah's College of Architecture + Planning is an agent of change toward better buildings. ITAC conducts activities with academic and industry partners, provides education in the form of teaching and workshops, and conducts outreach with university and community groups.	**LINK**

TABLE 7.3 OTHER USEFUL ON-LINE RESOURCES

OVERVIEW	ABOUT	TYPE OF CONTENT	LOCATION
STA VIDEO VAULT	Project and promotional videos from the timber offsite construction sector.	• Video • Animation	**LINK**
WOOD CAMPUS	A free Wood for Good online resource developed in conjunction with TRADA and accredited for Continual Professional Development (CPD) by the Royal Institute of British Architects (RIBA).	• Videos • Animation • Case Studies	**LINK**
CENTRE FOR OFFSITE CONSTRUCTION + INNOVATIVE STRUCTURES (COCIS)	A research centre within Edinburgh Napier University, Institute for Sustainable Construction (ISC) which works with building industry partners to research and commercialise innovation.	• Videos • Animation • Case Studies	**LINK (WEBSITE) LINK (YOU TUBE CHANNEL)**
ROBUST DETAILS	The robustdetails® scheme is the alternative to pre-completion sound testing for satisfying Part E of the Building Regulations. This online content provides guidance on acceptable details.	• Schematic details • Animations	**LINK**
CICSTART ONLINE	CIC Start Online hosts content form a European Regional Development Funded project in relation to planning of the built environment, sustainable building design, low carbon technologies, modern methods of construction building refurbishment and retrofit, and testing of building performance.	• Webinar Content	**LINK**
BUILD DESIGN + CONSTRUCTION	BD+C University offers architects, engineers, contractors, and building owners/developers who specialize in the commercial, industrial, and institutional markets an educational platform.	• Webinar Content	**LINK**
LOW CARBON BUILDING TECHNOLOGY GATEWAY	LCBT Gateway was a European Regional Development Funded project to develop in partnership with industry building solutions for a low carbon economy and sustainable communities.	• Webinar Content • Short Films • Animations	**LINK**
ARCHITECTURE AND DESIGN SCOTLAND (A+DS)	Architecture and Design Scotland (A+DS) is Scotland's champion for excellence in architecture, placemaking and planning.	• Exhibitions • Events • Workshops	**LINK**

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CREDITS

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