Material change for
a better environment

WAS003-001: Full Final Report

Current Practices and Future Potential in Modern Methods of Construction

Modern Methods of Construction (MMC) offer significant potential to minimise construction waste. This report identifies the current use of MMC, the potential for further uptake and the waste minimisation potential.

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1.1 Introduction

The overall objective of the research is to develop a detailed assessment of the current level of use of Modern Methods of Construction (MMC) and market size in different construction sectors, identifying positive and negative factors influencing take-up. The focus of the project is on developing a scoping document reviewing key products, markets etc, and the emphasis is on informing WRAP's work in waste minimisation and identifying markets where significant gains can be made.

In this report, we use the term MMC in preference to the term OSM (offsite manufacturing). This is because this term is increasingly being used instead of OSM and because it also includes several important new types of construction methods that involve some element of fabrication on site.

N.B. This report has been adapted from the report originally submitted to WRAP and any information deemed commercially sensitive has been removed in this version.

1.2 Objectives

The first phase was to develop a detailed assessment of the current level of MMC and usage in different construction markets (Health, Education, Housing etc), identifying positive and negative factors influencing take-up. The focus is on informing WRAP's work in waste minimisation and identifying markets where significant gains can be made.

Key research objectives in this phase included the following:

- Develop an overview of the current UK offsite construction market in terms of value, market share, key players, key construction sectors, benefits and drivers / barriers to growth.
- Identify and prioritise key companies and influencers in offsite construction – industry bodies, manufacturers, contractors, etc, - develop a database of contact details.
- Identify and categorise the range of various construction products and components manufactured offsite, together with examples.
- Evaluate the range of products and components in terms of market size, current sectors where used, split between UK manufacture and imports etc. In the major sectors, we would identify the leading 5-10 manufacturers (depending on sector size and structure) in terms of shares and provide contact details. Analyse and review the key application areas for the products/materials.
- Each of these key product / component sectors would be reviewed in terms of benefits and drivers to use, with a particular emphasis on their impact for waste reduction. In addition, key barriers to growth would be identified and a broad review of current standards, indicative material wastage levels, wider market potential and end-of-life potential for disassembly would be undertaken.
- Identify any emerging areas of MMC where possible.
- Identify manufacturers, products and components to be used as exemplars of offsite construction, in terms of highlighting a reduction in material wastage.
- Develop recommendations for key areas of offsite construction where WRAP should focus to achieve a decrease in material wastage.

The primary objective of the second phase of the research was to identify and prioritise the potential of different sectors of construction to adopt MMC to reduce construction material wastage. This phase of the project, therefore, focused on identifying key sectors and government initiatives where the potential to increase MMC is highest and provides the best opportunities for material waste reduction. Key research objectives in this phase include the following:

- Identify and prioritise construction industry sectors offering the best potential to increase the use of MMC – based on research in first phase.
- Each key sector will be assessed in terms of value, current and potential share for MMC, and key segments of sectors where MMC can be applied (e.g.: volumetric units, semi-finished 2-dimensional products, or at component/sub-assembly level)
- Identification and scoping of proportion of construction units where MMC can be applied.
- Comparisons with current waste levels from traditional build methods to develop views on where the greatest reductions can be achieved through MMC
- Identify existing /recent projects and case studies where construction waste has been minimised as a result of the use of MMC, which can be used as exemplar projects. Identify key personnel contact details.
- Identify future projects within key sectors offering potential for MMC and provide contact details, e.g.: Olympic Games, Building Schools for the Future programme, LIFT/ProCure21, MoD, Student Accommodation etc., are all sectors which would be reviewed.
- Develop recommendations for key areas of construction where WRAP should focus to achieve a decrease in material wastage.

1.3 Methodology

In overall terms the methodology for this project used a combination of the following:

- Desk research stage, incorporating analysis of existing data from relevant available reports, government sources, and any other secondary data sources, which become apparent.
- A primary research programme of interviews with offsite building product suppliers / manufacturers, main contractors, specifiers, industry consultants, trade associations etc.
- Analysis of findings and compilation of a detailed report, supplemented by a discussion meeting

1.3.1 Existing Data / Secondary Data

A wide range of published information sources were reviewed to assess current usage, players, key products/components, attitudes and trends towards offsite construction processes levels. Given the recent nature of the market and the rapid evolution of products and components, the level of published data quantifying the MMC market was limited, but key sources included Offsite Directory 2005, Government sources, company reports / websites / product catalogues, Trade Organisations/Associations, existing information from AMA Research knowledge bank, etc., with specific sources outlined below:

- Building Research Establishment/Arup: Market Transformation Programme draft report *Opportunities for Waste Reduction Through Modern Methods of Construction*
- Building Research Establishment: case studies - Greenwich Millennium Village, Chiswick Park
- Building Research Establishment: Waste reduction in refurbishment
- Building Research Establishment: Market Transformation Programme draft report *Waste Scoping Study: Waste Arising from Roofing Products (May 2006)*
- Building Research Establishment: Market Transformation Programme draft report *Waste Scoping Study: Waste Arising from Flooring Products (May 2006)*
- Buildoffsite: The value of the UK market for offsite (2004)
- Buildoffsite: Cameo case studies

- Association of British Insurers: Modern Methods of Construction: Insurance Considerations (February 2005)
- Commission for Architecture & the Built Environment (CABE): report for the Housing Corporation*: Design and Modern Methods of Construction*
- Cardiff University/Centre for Research in Built Environment: *Construction Waste Minimisation Good Practice Guide*
- Davis Langdon: Skyline 2006: Office Development Costs
- Envirowise: Saving money & raw materials by reducing waste in construction: case studies
- Envirowise: Saving money & raw materials by reducing waste in construction: case studies from Scotland
- Federation of Master Builders: Offsite construction: for and against
- Loughborough University: Offsite, Modern Methods of Construction in Housebuilding (January 2006)
- Loughborough University: Houseproud: practices & strategies of leading UK housebuilders on Offsite-MMC
- National Audit Office - Using modern methods of construction to build homes more quickly and efficiently (November 2005)
- Office for the Deputy Prime Minister: Survey of Arisings and Use of Construction, Demolition & Excavation Waste as Aggregate in England in 2003 (October 2004)
- Steel Construction Institute: Benefits of off-site steel construction in urban locations (2006)
- Steel Construction Sector Sustainability Committee: Sustainable Steel Construction - Building a Better Future: 1st annual report 2004
- TRADA Technology: Wood Used in Construction: The UK Mass Balance and Efficiency of Use (June 2005)
- TRADA Technology: Wood Used in Packaging: The UK Mass Balance and Efficiency of Use (June 2005)
- Viridis: The Construction Industry Mass Balance: resources use, wastes and emissions (revised 2003)
- AMA Research: range of market reports on timber frame, cladding, volumetric buildings, kitchen & bathroom pods etc

The desk research provided a significant amount of the data at product and market level, together with a substantial amount of the information on key companies, contractors, end use applications for offsite manufactured products.

1.3.2 Primary Research

The primary research programme was used to fill gaps in our knowledge. In certain sectors there was a need to undertake primary research to understand market sizes, potential for MMC, identify case studies on waste minimisation, and develop a better understanding of barriers to uptake etc. We interviewed a mix of the following organisations:-

- Offsite Building Product/Component Suppliers and Distributors.
- Building and construction contractors undertaking a range of private and public projects in all sectors.
- Clients and specifiers in key sectors
- Trade Associations, consultants etc.

MMC in the construction sector is a rapidly changing market and our view is that, given the wide range of product and component sectors, a telephone survey was the most effective way of developing a good understanding of key issues.

The summary mix of telephone, email and personal interviews is outlined below:-

Table 1: Primary Research – Interview Mix	
Sector	Telephone/ Email
MMC product suppliers and manufacturers	56
Trade associations/MMC research organisations	15
Main contractors, housebuilders, specifiers etc.	67
Total	138

1.3.3 Data Collation, Assessment and Report Preparation

Output from the research includes a market assessment of current usage of offsite construction products and components, together with drivers and barriers to growth. In addition, the report includes a market assessment of future potential for MMC in key sectors and provides recommendations on key areas of focus for WRAP to deliver a decrease in material wastage through the use of offsite construction.

In addition, a separate Excel database has been developed of major offsite manufacturers, products and components, together with key stakeholder contacts. This list highlights in bold key companies and contacts where the level of involvement and/or commitment to MMC is considered to be high and would be worth considering for follow-up contact**.**

1.4 Summary

1.4.1 Key waste streams arising from traditional construction methods

The table below provides a summary of the key waste streams arising from traditional construction methods. The figures are derived from case studies provided by contractors and other research organisations. It needs to be strongly emphasised that volumes of waste and the mix of waste material entering the waste stream for disposal vary considerably according to a combination of factors including: the type and size of development, the mix of materials and products used, the nature of the sites (size, accessibility etc) and the waste management procedures at each site – these variables are reflected in the ranges shown in the table below. However, across the various case studies, there is generally a high level of consistency with regard to waste mixes.

Table 2: Key Construction Material Waste Streams on Traditional Newbuild Schemes	
	Modal Average - Range %
Packaging (incl. wood pallets, cable drums, cases)	25 - 35
Plasterboard	5 - 36
Rubble – broken bricks, blocks, tiles etc	25 - 40
Timber - (excludes pallets)	15 - 25
Cement and plaster	10 - 17
Insulation – rockwool and fibreglass	6 - 15
Metal	3 - 9
Dry concrete products – blocks, slabs etc	2 - 12
Plastic products (excludes packaging)	1 - 11
Ceramic material	1 - 8
Source: AMA Research/trade estimates	

The table above highlights that packaging, rubble, plasterboard, timber, cement/plaster and insulation are consistently the main waste streams. It is important to emphasise that the figures purely relate to material that is skipped, whether the skips are for mixed or segregated waste. This does not include offcuts or unused materials and products that are set aside for recovery and recycling. This issue is best demonstrated by plasterboard. Typically, on large schemes managed by major contractors, where substantial volumes of plasterboard waste –supplied by British Gypsum - is generated – this will often be recovered for reprocessing and, consequently, this will not be recorded as waste.

Based upon our primary research, the table below summarises which elements of the construction process are typically generating the key wastes by material and product type and rank these accordingly. Therefore, for example, the use of aircrete blocks for inner leaf construction generates a high level of waste in terms of the packaging required for their delivery to site (wood pallets and shrink wrap) plus the waste generated from their assembly in the form of broken and unused block and unused mortar.

Table 3: Key Waste Streams by Application

(3 = generally high, 2 = reasonably high, 1 = noticeable, blank = not relevant or negligible)

Applications	Packaging material waste streams							Building product/material waste streams							
	Wood pallets	Shrink wrap	Card-board	Metal tins – paint, pres.	Plastic tubs – mastics etc	Plastic bags	Paper	Timber	Con-crete	Plaster-board	Panel prods.	Sheet or roll prods.	Bricks, blocks tiles	Cement mortar plaster mastic	Bldg services prods
Roofing															
Rafters, joists etc								3							
Battens								2							
Tiling	3	3			2								3	1	
Insulation		2	1								2	2			
Membranes												3			
External walls															
Block inner leaves	3	3											3		
Brickwork	3	3											3	2	
Cladding		1						2			1				
Windows & doors	1	2			2			1							
Cavity wall insulation		3	1									3			
Cements, mortars, render	2						1				1				
Flooring															
Ground flooring								3*	3			1			
Ground floor insulation		3	1									3			
Columns								3*							
Decking								2							
Site peripherals															
Hoardings								3							

Notes to the above table – *neither shallow nor deep types of foundation systems are included as very little concrete over-burden is typically generated* **timber waste associated with in-situ concrete ground floors and columns relates to discarded plywood formwork*

Table 3 Continued															
	Packaging materials waste streams							Building product/material waste streams							
Interior fit-out	Wood pallets	Shrink wrap	Card-board	Metal tins – paint, pres.	Plastic tubs & guns – mastics	Plastic bags	Paper	Timber	Con-crete	Plaster-board	Panel prods.	Sheet or roll prods.	Bricks, Blocks, Tiles	Cement mortar plaster	Bldg services prods
Interior/party walls															
Plasterboard	3	2								3				2	
Plastering							1								
Paint work etc				3	1		1								
Interior windows					3										
Plumbing equipment		3	2												2
Electrical equipment		3	2												2
Heating equipment		3	2												2
Lighting products		3	2												
Bathroom fittings		3	3			1	1								
Ironmongery		3	3			2	3								
Interior doorsets		3	3				2								
Fitted kitchen	3	3	3					3							
Wall & floor tiling		2	3		2								1		
Floorcoverings		2	2		2										
Mouldings								3							

Source: AMA Research/trade estimates

Notes to the table:

The ratings in the table are derived from a survey of the main contractors and leading housebuilders. The quality of information provided ranges from broad estimates to specific project site assessments of waste arisings and mixes using the BRE's SMARTWaste system. However, as responses were generally consistent, our confidence in the data is high.

1.4.2 Key MMC product sectors

In considering the key waste arisings and the construction activities generating them, as identified in the above table, we have developed a list of MMC products that could possibly make a contribution towards reducing construction site waste where they are substituted for traditional building methods and materials. To date, the use of MMC products has been fairly limited, reflected in the fact that the MMC sector accounts for around 7 - 8 % of the total UK markets for building materials and products. The potential for the use of MMC to contribute towards minimising site waste is dependent on many variables:

- The extent to which particular MMC are established in the UK and whether they have recognised accreditations from the BBA, British Standards, BRE, ISO9000 and the NHBC etc.
- Current industry market size and manufacturing capacity and the potential for growth in order to meet potential increase in end-user demand.
- Perceptions among specifiers and client organisations of MMC with regard to the quality, cost-effectiveness and also their levels of knowledge and experience with MMC.
- The strength and effectiveness of traditional construction lobby organisations, such as the Traditional Housing Bureau, in attempting to curb the use of MMC.
- The current size of existing end user markets for the various types of MMC and the planned anticipated growth levels in these markets plus their potential for the penetration of new end-user markets.
- Design trends. MMC is generally perceived as being best suited, and indeed has mostly has been used, for applications where there is a uniformity in building design and a repeatability of design e.g. buildings with cellular accommodation.
- Comparative costs between traditional methods of construction and MMC on a project basis. In general, cost still remains the over-riding factor in specifications and has been a key reason for the slow uptake of many types of MMC in the UK.
- Potential for economies of scale. MMC are generally well suited to projects where economies of scale can be achieved through factors such as uniformity, simplicity or functionality of design, combined with high-volume requirements.
- Site factors such as size of site, availability of site storage space, degree of accessibility and vehicle/plant manoeuvrability are key factors determining construction methods.
- Skilled labour issues. A key factor driving up demand for certain types of MMC has been the shortage of available skilled labour, especially in the electrical, plumbing and carpentry trades. With the 2012 London Olympic Games construction programme absorbing a large volume of labour away from other developments, this is likely to weigh heavily in favour of MMC.

The table below summarises some of the key issues outlined above with regards to the various types of MMC we have selected as possible solutions to reducing site waste over the short to medium term.

Table 4: Selected Key Types of MMC – Market Size and Construction Applications

Types of MMC	Vol. prod-cap.	UK market £m MSP	Avg growth rates p.a. % 2000 - 2005	Est. % of imports	Main Existing Areas of Construction Application
Volumetric modular	Med	200	10 –15	10 -15	Cellular single living accommodation: MoD, prisons, KWL, budget hotels; out-of-town retail back offices; forecourt stores; stand-alone fast food outlets; hospital wards & operating theatres; primary schools & nurseries; university tutorial blocks; school classroom extensions; 3-4 star hotel extensions; sports pavilions; shower blocks; airport terminal buildings: social housing apartment blocks
Panellised modular		565			
Timber frame	High	475	40 - 45	5 - 10	Up to 4 storeys - private and social housing
Pre-cast	Med	80	10 - 20	5 - 10	Up to 6 storeys - cellular single living accommodation: student accommodation, KWL, hotels; private housing; apartment blocks; school buildings; industrial buildings; prisons
Steel frame	Low	25 - 35	5 - 10	0	Mostly 2 storeys - private and social housing
SIPS/SIRPs	Low	30 - 35	5 - 10	30 - 40	Up to 6 storeys - private and social housing
Building envelope		545			
Composite panels	High	325	4 - 6	10 - 20	Mostly industrial buildings, warehousing, out-of-town retail, business park offices
Pre-cast cladding	High	120	5 - 8	5 - 10	Mostly bespoke/prestigious architect-designed buildings
LSF systems	Med	50	20 - 30	5 - 10	Large facades/high-rise – apartments, SLA, hospitals, hotels, airport buildings, retail
Pods	High	125	40 - 50	50 - 55	Cellular single living accomod'n: MoD, prisons, hotels rooms, student halls of res.; apartment blocks
Pre-cast structural	Med	110	Mixed	Low	Varied & wide-ranging depending on the type of products
Insulating concrete formwork	Low	20	N/a	Low	Mainly housing
Tunnel form	Med	130 *	Strong	Low	Large-scale cellular construction developments

Source: AMA Research/trade estimates

Notes to the table:

Table headings

Vol. Prod. Cap. – volume production capacity. This is our term to help identify which sectors of the MMC/MM have the capacity to be able to manufacture products and systems in high volumes. High indicates that there are at last several large manufacturers or importers/suppliers that together generally have the capacity to be able to meet significant surges in demand from existing markets.

Medium indicates that the UK supply sector is well established and relatively large within the context of MMC. However, we consider that industry capacity to supply on a high-volume basis is limited due to factors such as long-term commitments to specific large contracts or because most major manufacturers tend to supply on a bespoke basis.

Low indicates that these particular sectors are either small and/or they generally operate on a bespoke and/or supply and fix basis and do not yet have the facilities to manufacturer on a large-scale. Therefore:

Timber frame – there are around 6 high-volume suppliers with annual capacities of at least 3,000 units a year, and which are able to supply on a third party basis. There are also other major UK and Continental suppliers able to meet volume growth in demand.

Pods – there are around 8 suppliers with an annual supply capacity of at least 3,000 units p.a. plus another 10 with a combined capacity of 10,000 – 15,000 p.a.

Composite panels – this is a maturing sector consisting of several large manufacturers able to meet large-scale demand from end-use sectors that are relatively mature and showing low growth

Pre-cast cladding – this is a long established sector supplying a high-value niche market where annual growth rates are fairly consistent

Volumetric & panellised steel frame systems - currently the only two manufacturers with the capacity for volume production are Corus Living Solutions and Kingspan Offsite. Most of the other major manufacturers supply bespoke systems on a supply and fix basis and do not have current ability to supply in high volumes. Further more, some - e.g. Corus Living Solutions – have all or most of their production capacity tied up over the next 5 –8 years.

LSF systems – this sector is currently expanding at a steady rate due to the expansion of existing capacity at some key suppliers plus new market entrants

SIPS/SIRPs– these sectors are still small with few suppliers that can manufacturer on a volume basis. In the UK SIPS sectors most are small suppliers of bespoke systems.

Table data

** Tunnel form - the figure of £130m is given at installation prices*

Re: owing to factors such as product definition, lack of trade or Government data etc. the data in the above table should be treated as estimates only

Table 5: Key Types of MMC by Main End User Sectors

(Key 3 = key markets, 2 = some current usage, 1= potential use, blank = limited application)

	Single living accommodation				Residential		Education		Healthcare			Leisure		Other			
	MoD	Stud. accom	KWL	Prison etc	House	Flats	Class-rooms	Other bldgs	S'con h'care	Prmry h'care	Care homes	Hotels	Other	Retail	Airprt bldgs	Arch'l	Ind/ Bus. pk
Volumetric	3	2	2	3	2	2	3	2	3	2	2	2	3	3	3		2
Timber frame		2	2		3	3		3		2	2		2			2	
Pre-cast panels	3	3	1	1	3	1	2	2		1	1	3	1	1			3
Steel frame	1		1		3					1	1	1	1	1			1
SIPS/SIRPs					3	3				1	1	1	1				
Comp. panels	1						2	2	3				3	3	3	2	3
Pre-cast clad						3		3	3			3		2		3	
LSF systems	3	2	1			3		2	3	1	1	3	1	1	2	2	1
Pods	3	3	3	3	1	3		2	2	1	2	3	2		2		
Pre-cast structural	3	2	2	3	3	3	2	2	3	3	2	3	2	3	3	3	3
ICF					1												
Tunnel form	1	3	1	1	1	1						3					

Source: AMA Research/trade estimates

Notes to the table:

1 – Education – 'classrooms' includes teaching blocks I, Other buildings includes shower blocks, pavilions, sports centres/gymnasiums

2 - Leisure – 'other' includes sports centres, pavilions, shower blocks, visitor centres

3 – Architectural – includes all types of bespoke, prestigious or high value end-user applications e.g. shopping malls, corporate head offices, luxury apartments

4 – Retail – refers to standardised construction e.g. forecourt stores, fast food outlets, retail park stores etc Excludes bespoke e.g. shopping malls, dept stores

5 – Industrial, business and retail parks – this covers all types of buildings typically located on these types of development including industrial warehousing

Coding

'3'/green - indicates that the end-user sectors identified are key markets for these type of MMC. E.g. volumetric construction is currently being used extensively on MoD single living accommodation

'2'/ orange - indicates that these end use sectors are not generally key markets for these types of MMC, but nevertheless they have achieved some penetration and have shown that the use of these types of MMC in these sectors is viable.

1'/blue - indicates that current use of MMC products in the end use sectors identified is limited but that we anticipate there could be considerable potential for increased penetration in these markets. The assumptions here are that over the medium-longer term, contractors' output is set to increase significantly and that these types of MMC are well suited to the high volume, standardised design, fast-track construction methods used in these areas. For example, tunnel form construction is a very fast and efficient way of building large cellular units such as student halls of residence and prisons, but that to date, its use in the UK has been limited to just a few projects.

1.4.3 Opportunities for reducing waste through the substitution of MMC

Table 6: Summary of Potential of Key Types of MMC for Reducing Site Waste

Solution ratings: 3 = significant reduction, 2 = moderate reduction, 1 = limited impact, blank = no reduction, or N/A = not applicable

	Packaging material waste streams							Building product/material waste streams							
	Wood pallets	Shrink wrap	Card-board	Metal tins – paint, pres.	Plastic tubs & guns – mastics etc*	Plastic bags	Paper	Timber	Con-crete	Plaster-board	Panel board prods ***	Sheet or roll insulation.	Bricks, blocks tiles	Cement mortar plaster	Bldg services prods
Volumetric	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2
Timber frame*	3	3	1	1	1	1	2	3	1	3	2	1	3	2	N/A
Pre-cast panels	3	3	2	1	1	1	2	3	2	2		3	3	3	N/A
Steel frame	3	3	2	1	1	1	2	3	3		1	3	2	3	N/A
SIPS/SIRPs	3	3	2	1	1	1	2	3	2		3	2	3	3	N/A
Composite panels	2	2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3	N/A	N/A	N/A
Pre-cast cladding	3	3	2	N/A	N/A		N/A	3	N/A	N/A	N/A	2	2	N/A	N/A
LSF (open)	3	3	2	N/A	2	2	N/A	3		N/A	3	1	3	3	N/A
LSF (closed)	3	3	3		2	2		3		N/A	3	3	3	3	N/A
Pods	3	3	3	2	2	2	2	1	1	2	N/A	1	2	2	2
Pre-cast structural**			N/A	N/A	N/A	N/A	N/A	3	3	N/A	N/A	N/A	N/A	3	N/A
Insulating concrete formwork	2	2	N/A	N/A	N/A	N/A	N/A	2	2			2		3	N/A
Tunnel form	3	3	N/A	N/A	N/A	N/A	N/A	3	3	1	2	N/A	3	3	N/A

Source: AMA Research/trade estimates

Notes to the table:

**The level of pre-fabrication for timber frame systems ranges from simple open-frame wall panels and trussed rafters (or other roofing systems) with concrete ground flooring, to closed panel building systems comprising plasterboard, insulation, breather membranes, timber floor cassettes etc all but the interior fit-out. In the above table, out assumption is based on the most common type - open-panel systems comprising vertical studs and horizontal rails, trussed rafters, timber floor cassettes, wood-based panel sheathing, plasterboard lining and an external breather membrane. Excluded are thermal insulation and all interior fit-out components. It should be noted that re; bricks/blocks/tiles we give a '3' rating as the use of timber frame negates the need for inner leaf blockwork and although brick cladding is typically required, recovery of bricks for recycling is increasing.*

*** Pre-cast structural (components) comprise the broadest range of products, but for the purpose of this report excludes pre-cast panels, as these are treated as a separate product group. Most pre-cast structural components*

**** panel board products – includes particleboard, OSB boards, drylining etc*

The table above summarises our views on the extent to which the main types of MMC shown can possibly contribute towards a reduction in construction waste levels, where they are substituted for traditional building methods. However, it needs emphasising that these responses should be treated as broad indicators, due to the general lack of firm data.

Colour coding

'3'/green - indicates that there should be sufficient capacity among suppliers to be able to meet increased demand over the short-medium term and that the types of MMC identified do contribute to significant reductions in the product/material waste streams indicated. For example, volumetric construction eliminates all waste except that generated through excavating foundations and a small amount of offcuts from connecting the services pipework/cabling to the mains.

'2'/orange - suggests that the types of MMC identified are likely to have a reasonable level of impact upon reducing waste levels in the product/material areas indicated. However, there will be some need for traditional products/materials that will inevitably generate waste. For example, with SIPS, there is no need for site-installed cavity wall insulation, but sheet insulation is typically needed for the ground floor.

'1'/blue suggests that substitution of the identified type of MMC would lead to a small reduction in the types of waste indicated.

A blank space indicates that where these types of MMC are used, there are still similar volumes of waste being generated in these areas as with traditional building methods. For example, with timber and steel frame systems, plasterboard still has to be cut and installed on site, the same as with brick and block construction.

***N/A** indicates that the use of MMC is not applicable where addressing the types of waste streams listed. For example, composite panels and pre-cast cladding are mostly used as alternatives to on-site cladding and façade glazing. Therefore, products such as paint, cements & mortars, building services products and associated packaging are not relevant.*

Table 7: MMC & Estimates of Waste Reduction though Substitution for Traditional Building Methods		
MMC	Est. % reduction	Level of confidence
Volumetric building systems	70 - 90	Reasonable
Timber frame systems	20 - 40	Broad estimate – depends upon the level of pre-fabrication
Concrete panel systems	20 - 30	Broad estimate
Steel frame housing systems	40 - 50	Broad estimate
OSB SIPS	50 - 60	Reasonable – depends on the level of prefabrication
Composite panels	20 - 30	Broad estimate
Pre-cast cladding	40 - 50	Broad estimate
LSF systems	40 - 70	Reasonable – depends on the level of prefabrication
Bathroom/shower & kitchen pods	40 - 50	Broad estimate
Pre-cast flooring	30 - 40	Broad estimate
Thin joint masonry	30 - 40	Broad estimate
Insulating concrete formwork	40 - 50	Broad estimate
Tunnel form construction	50 - 60	Broad estimate
Source: AMA Research/trade estimates		

The chart above illustrates estimates the levels of site waste reduced using these types of MMC compared to equivalent traditional construction methods. They are not indications of the levels of contribution to total waste reduction. For example, it is estimated that using bathroom pods saves up to 50% of the waste typically generated from fitting out a bathroom the traditional way.

It is important to note, however, that while some of these estimates are based upon real life case studies, others are based upon estimates and anecdotal evidence given by respondents in interviews.

1.4.4 Ease of disassembly

The following figure provides a summary of the relative ease with which the various types of MMC products under review are likely to be able to be disassembled at the end of life. It is important to note that these are largely assumptions based upon interviews with manufacturers and an assessment of how these products are manufactured. For example, with products assembled using fasteners such as rivets, bolts, brackets etc – as opposed to adhesives, cements and mortars – it is generally assumed that they should be easy to disassemble. In reverse, the assumption is that where components are fastened using mortars, cement or adhesives they are likely to be relatively difficult to disassemble without demolishing them.

Table 8: Main MMC & End of Life Disassembly for Recycling

MMC Products	Comment
Volumetric building systems	Fastening systems enable ease of disassembly. Main components for recovering for recycling include: light steel frames, cladding, drylining, membranes
Timber frame systems	Easy to disassemble. Most components suitable for chipping but wood treatments make post-use timber unsuitable for some recycling applications
Pre-cast panel systems	Easy to disassemble. Suitable for crushing for use as recycled aggregate
Steel frame housing systems	Fastening systems enable ease of disassembly. Main components for recovering for recycling include: steel frames, cladding, drylining, membranes & insulation
OSB SIPS	Fastening systems enables ease of disassembly. OSB panels can be chipped and urethane insulation core can be powderised.
Composite panels	More difficult to disassemble and recycle where urethane insulation core bonds to panels. Where insulation core is mineral wool, fastening system makes disassembly easy
Pre-cast cladding	Suitable for crushing for use as recycled aggregate
LSF systems	Fastening systems enable ease of disassembly. Main components for recovering for recycling include: light steel frames plus cladding, drylining, membranes & insulation on closed systems
Bathroom/shower & kitchen pods	Easy to disassemble. Steel frames can be recovered for recycling but not the ceramic ware and plastic shells
Pre-cast structural panels, flooring	Not easy to separate insulation from pre-cast leaves

Source: AMA Research

1.4.5 Conclusion

The figure below encapsulates the findings in the survey and identifies the potential for the reduction of site waste through the substitution of MMC in existing and potential key end use markets:

Table 9: Key Areas of Potential for Reduction of Site Waste though the Substitution of MMC

End users	Construction output 2006 - 2012	Current level of use of MMC	Potential for increasing uptake of MMC	Potential for waste reduction through increased use of MMC	Key drivers for MMC
MoD	Increasing substantially to 2012	Very high	Significant	Significant	MoD (Debut Services & Carillion) very pro-active. Requirements for fast-track construction & minimum disruption
Student accommodation	Expected to increase to at least 2012	Very high	Moderate due to current high usage	Significant	Requirements for fast-track construction & minimum disruption
NHS	Increasing substantially to 2020	Low - moderate	Substantial but dependent on specifiers	Significant	Main contractors. Requirements for fast-track construction & minimum disruption
Schools	Increasing substantially to 2020	Low - moderate	Substantial but dependent on specifiers	Significant	Requirements for fast-track construction & minimum disruption
KWL	Increasing over short term	High	Significant	Significant	Affordable Housing
Social/Affordable housing	Increasing over longer term	High	Significant	Significant	Housing Assn, Affordable Housing, progressive builders
Private housing	Increasing over longer term	Low	Significant but dependent on clients & specifiers	Significant	NHBC, progressive builders
Prisons etc	Possible increase	High	Moderate – depending on Govt plans	Moderate - as MMC used	HM Prison Service policy on sustainable development
Hotels	Moderate over short term	High	Moderate due to current high usage	Moderate	Budget hotel sector- requirements for fast-track construction for early revenue generation
Retail	Moderate	Low - moderate	Moderate due to limited applications & low growth in sector	Moderate	Convenience store chain operators, fast food chain operators- requirements for fast-track construction for early revenue
Olympic games	Increasing substantially to 2011	N/a	Substantial – athletes accommodation	Significant	Requirements for fast-track construction + issues of labour availability

Source: AMA Research

1.5 Glossary of terms

Listed below are terms and abbreviations that are used more than once in the report. Where a term is just used once, an explanation is provided.

Cross-wall – a type of pre-cast concrete panel system used for the rapid construction of buildings. It typically consists of floors, load-bearing external and party walls, with pre-formed window apertures, used for the fast building of room shells.

BBA – British Board of Agrement.

BRE – Building Research Establishment.

BSF – Building Schools for the Future (programme).

BS – British Standards.

Composite panels – also called sandwich or insulated panels. These are cladding panels comprising two rigid skins and a core of insulation material, usually foam but sometimes rockwool or mineral wool.

Envelope - industry term that covers external wall cladding, glazing and roofing.

EPS – expanded polystyrene.

Fast-track - type of construction covering several innovative building system designs to accelerate the overall construction period on-site with the resulting time and cost benefits.

GRP - glass reinforced plastic.

Hollow-core - type of floor system comprising slabs made from pre-cast pre-stressed concrete elements with continuous voids provided to reduce self-weight and achieve structural efficiency.

ICF - insulating concrete formwork**.** A factory-made formwork system comprising twin-wall expanded polystyrene (EPS) blocks or panels, which are assembled to create the external walls of a building.

KWL - Key Worker Living accommodation: Government initiative designed to help certain key public sector staff (key workers) to access affordable housing, buy their own home or find more suitable accommodation when their housing needs change.

LSF - light steel frames: these are typically non-load-bearing elements used to support components such as external wall insulation and cladding. The most commonly used system is that of site-assembled or 'stick' systems, which consist of standard lengths of light gauge steel that are cut to length on-site. Increasingly, pre-assembled frames are being specified. These range from simple frames to pre-fabricated panels comprising the drylining, insulation and cladding elements.

MMC - Modern methods of construction: includes prefabricated products made in the factory and also new methods of building that are site-based e.g. tunnel form construction and insulated concrete formwork. This term is rapidly replacing the older term, off-site manufacturing (OSM), in recognition of the fact that several new methods are site-based rather than pre-fabricated.

MoD - Ministry of Defence.

MSP - manufacturers sales prices.

MTP – Market Transformation Programme.

NHBC - National House Building Council.

OSB - oriented strand board. Panel products manufactured by gluing and high-temperature pressing of layers of thin wood chips, with each layer oriented at a right angle to adjacent layers.

Panellised modular construction – form of building whereby panels are delivered to site in flat-pack format, are craned into position and joined together. Panels supplied typically include those for the external walls, the party walls and flooring and sometimes the roof element. The main types are timber frame, steel frame, pre-cast concrete and SIPS.

Pods - pre-fabricated 3-D non load-bearing modules typically used for bathroom, shower room, kitchen and public toilet/washroom applications, usually used in conjunction with steel or concrete main frames.

RSL - Registered Social Landlords (formerly Housing Associations).

SCI – Steel Construction Institute.

SIRPs - structural insulated roofing panels: these are complete factory-made roofs supplied to site in flatpack format. Currently there are few suppliers in the UK offering this product.

SIPS - structural insulated panels are load-bearing panels comprising two sheets, mostly of oriented strand board (OSB) with a foam insulation core.

SLA - single living accommodation: broad term used to cover various types of residence for single people, the main end-use applications being the defence sector, students and KWL.

SLAM – Single Living Accommodation Modernisation (programme). Major project being undertaken by Debut Services on behalf of Defence Estates for the upgrading of single living accommodation across all the services.

Thin Joint Masonry – system comprising aircrete blocks with tight tolerances and a specially developed mortar that is used in smaller quantities than standard mortar and dries much more quickly.

Tunnel form construction – type of site-based MMC using a formwork system that allows contractors to mould on-site the external wall, floor slabs and party wall elements simultaneously. Mainly used for large multi-cellular buildings e.g. student accommodation.

Volumetric modular construction – form of building using 3-D modules that are typically supplied to site completely fitted out. They are either installed within a main structural frame or where self-supporting they are stacked on top of each other.

2.0 Construction Waste Arisings

2.1 Construction & demolition waste overview

According to studies undertaken on behalf of the ODPM, construction and demolition waste arisings in England for 2003 were equivalent to around 90m tonnes. Most of this, however, is demolition and excavation waste comprising spoil, excavated soil and rubble. Hard C & D waste – mostly comprising brick and block, tiles, timber etc. – was around 44m tonnes, although this is not split out between the different construction, demolition and excavation waste streams. With traditional methods of building, the main practices generating waste have generally been:

- Over-ordering - this has particularly been the case on projects where short project times and tight deadlines have been specified. Typically, in anticipation of product breakages, inaccurate measurements etc., contractors have tended to deliberately over-order on lower cost items e.g. standard lengths of timber, mouldings, bricks and blocks, insulation etc.
- Exposure of wood products to the elements, which results in damage through soaking and warping. This also includes site hoardings.
- Cutting, shaping and mixing materials on site generating offcuts and unused/unusable product – this mainly relates to timber and composite wood products (e.g. OSB and particleboard), rockwool and glasswool insulation, membranes and mix mortars, plasters, cement

2.2 Construction waste mixes

With regard to construction waste, arriving at definitive totals and waste mixes based on project samples is difficult, primarily due to the wide variation in project types and materials used. The table below, however, summarises several independent studies on construction waste arisings, although it needs to be strongly emphasised that the robustness of data varies, reflecting the composition of the various case studies. Although there is variation in the relative sizes of the different material waste streams, it is evident that the largest are packaging, timber, plasterboard, cement & plaster, bricks & blocks and insulation. This is supported by our findings from our primary research phase, where we asked respondents to rank what they consider to be the main product waste streams by type of activity.

Table 10: Key Construction Material Waste Streams on Traditional Newbuild

Waste material	Modal Range %
Packaging (incl. wood pallets, plastic, cardboard, tins)	25 - 35
Plasterboard	5 - 36
Broken bricks, blocks, tiles etc - housing	25 - 40
Timber - (excl. pallets)	15 - 25
Cement and plaster	10 - 17
Insulation – rockwool & fibreglass	6 - 15
Metal	3 - 9
Dry concrete products – blocks, slabs etc	2 - 12
Plastic products (excludes packaging)	1 - 11
Ceramic material	1 - 8

Source: AMA Research from various case studies

2.2.1 Packaging

The largest source of waste is packaging generated by sub-contracting activities, the key areas being interior fit-out, roofing, insulation and heavyside materials i.e. bricks, blocks, roof tiles and cement and mortar mixes. The main types of packaging waste appear to be discarded/broken pallets, followed by shrinkwrap, tins - for liquid materials including paint, preservatives, mastics, varnishes etc - and cardboard.

Wood packaging

Packaging accounts for around 11% of total timber use in the UK. By far the largest product sector is that of pallets, which are estimated to account for around 87% of all wood packaging, equivalent to between 1.04m - 1.25m tonnes (depending on information sources). Wooden cases account for 8 - 9% with all other types 4.2%. The construction industry is the largest area of demand for wood packaging, accounting for around 26% of demand.

It is estimated that the construction industry accounts for around 290k - 330k tonnes p.a. of pallets. Pallets are used in the delivery of a broad range of products, including: concrete blocks for inner leafs and foundations, bricks, roof tiles, fitted kitchen units, bathroom/toilet ware, 'white goods', plasterboard, and sheet and roll products such as fibreglass and rockwool insulation and membranes. Other products sometimes supplied on pallets include glazing and cladding products, and structural timber – though most of these are delivered to site on stillages.

It is difficult to ascertain what proportion of pallets are landfilled, but anecdotal evidence suggests that it is high. Although difficult to quantify, some clear issues emerged during our primary research:

- Many of the medium-larger housebuilders and construction companies, particularly those active in the social housing sector, have sufficient influence over their supply chains to demand that suppliers recover their pallets. Furthermore, large developments and refurbishment projects make it economically viable for suppliers to take back their used pallets.
- The other key driver is that some RSL's are ultimately influencing sustainable site practices throughout their supply chains.

As a result, pallet wastage is largely arising where it is generally neither economically viable for suppliers to take back their pallets, or where users are unable to persuade them to take back their pallets. However, our research indicates wide variations in practice and there are some large housebuilders and contractors whose approach is to leave all waste control decisions with their subcontractors.

Other packaging

Our primary research shows clearly that after pallets, shrinkwrap and cardboard are the largest packaging waste streams. Shrinkwrap and cardboard together are mainly used for the following products: fitted kitchen components, fitted bathroom and toilet components, 'white goods', lighting and heating products, glazing, floorcoverings, plumbing & electrical products, wall & floor tiles etc. Shrinkwrap is also used extensively with products and materials typically supplied on pallets namely bricks, blocks, sheet/rolled insulation products, membranes and interior doorsets.

Cardboard boxes and plastic bags are key elements of packaging waste, used for ironmongery, plumbing and electrical components - such as flanges, joins, sockets and switches etc - and door and window furniture goods.

The other key packaging waste is that of discarded metal tins and plastic pots used for paint, varnishes, wood protection, mastics, putties etc.

2.2.2 Timber construction products

Each year, there are around 1.1million tonnes of wood waste arisings in the UK construction industry. By far the largest source is sawn and shaped softwood, which accounts for over 70% of this, equivalent to around 800k tonnes.

Most softwood waste appears to be sawn offcuts and unused lengths generated on small-medium construction projects, especially brick and block housing newbuild, refurbishment and RMI works. A typical 2-storey, 2-3 bedroom brick and block new house will require around 5 – 6 m3 of wood, 80% of which is softwood. Combining information from our primary research and other sources, the main activities generating large volumes of wood waste are:

- The use of plywood formwork on ready mix concrete and concrete blockwork on ground floor construction, and as shuttering for the protection of concrete columns. Formwork is typically used once or twice at most and is then discarded.
- Cutting interior doorframe materials to size on refurbishment and RMI works, due to the lack of standard door sizes on many older properties.
- Sawing to length structural roofing timbers, mostly on irregular pitched roofs and on small - medium sized housing developments. On high-volume housing newbuild there is a greater use of pre-fabricated truss rafters.
- Sawing to length of mouldings, especially skirtings, as these are supplied in standard lengths.
- Ordering over-sized material on projects where there are tight time-scales rather than risk ordering material that could be over-cut and need replacing.
- Reworking, arising from inaccuracies in design drawings or misinterpretation. This appears to be a significant problem with regard to fitted kitchens. Sawing kitchen worktops to length is also a significant source of offcuts waste.

From our primary research it was also made clear that the autumn and winter seasons are times when wood waste is higher than average, due to outside storage of timber components, which become spoilt in bad weather.

The use of hoardings is also a major source of wood waste as these typically have single usage after which they are either burned on-site or skipped.

Of this 1.1 million tonnes of wood waste generation, it is estimated that at around 150k tonnes p.a. is sent to landfill, with around 300k tonnes p.a. burnt as fuel.

2.2.3 Bricks & blocks

Broken bricks and aircrete blocks, and unused aircrete blocks are a key waste stream on housing newbuild developments and are also significant in other end-use sectors where brick and block construction is still widely used e.g. schools and hospitals. Blocks are also commonly used in for inner leaf construction in conjunction with timber frame, concrete and steel mainframe construction. A key problem appears to be that aircrete blocks are a cheap product, costing around £2 a block and as such there is little incentive among tradesmen to recover blocks for later use.

Some contractors and housebuilders do have policies for crushing waste bricks, blocks and other rubble on-site for use as aggregate fill material but, in general, most of this waste is disposed of as mixed waste in landfill.

2.2.4 Plasterboard

Some major construction companies have arrangements in place with British Gypsum for the recovery and on-site segregation of their own (waste) plasterboard products from sites that are sufficiently large enough to warrant recovery for processing. In general, plasterboard is a key waste material that, on high-rise apartment schemes, can account for as much as around 35% of total waste arisings.

The main cause of plasterboard waste appears to be damage, whether arising from careless handling or storage and exposure to the elements. The other main problem is that installers have a wasteful approach to using the material. As a project manager from one leading housebuilder noted:

"Plasterboard off-cuts are a significant waste stream. It seems to be industry practice to use a new board to cut a small piece and then to throw the remainder of the perfectly good board in the skip. Off-site fabrication or room size standardisation would reduce or eliminate this."

On luxury apartments and prestigious/bespoke office developments, it is common practice to use two skins of plasterboard and if there is just minimal or superficial damage they will usually skip whole boards.

2.2.5 Mortar, cements, plaster & grouting

Unused or excess mortar used for block assemblage and pointing for brickwork is probably the largest source of waste here followed by unused plaster. The main problem is that as the average cost of these materials is low, tradesmen tend to mix too much material. It has been noted that where more expensive mortar is used with Thin Joint masonry, contractors tend to be much less wasteful.

2.2.6 Insulation

The level of insulation waste varies from one type of building to another, depending on the type of insulation materials used. The use of foam and bats of rockwool, used in cavity walls typically generate little waste. The use of rockwool and fibreglass rolls on loft insulation also appears to generate little waste, as spare lengths will be used to bolster those areas most subject to heat loss.

From the primary research it is apparent that the main applications generating significant waste volumes are:

- Sheet insulation and polystyrene blocks used on ground floor applications were reported as being key problem areas due to the volume of waste typically arising. Some of our respondents indicated waste levels of up to 15%.
- Unused material used in cavity wall insulation can also be significant, especially where standard sizes of rockwool and fibreglass insulation are specified.

It was also reported that damage resulting from poorly stored materials could also be a key source of waste arisings.

2.2.7 Other waste

This sub-section provides a briefly summary of the other types of construction waste.

Metal – the key source of metal waste appears to be offcuts from light steel 'sticks' used in the construction of facades. While offcuts waste can be up to 20%, this is almost always recovered for re-processing. The other main source is the installation of standardised metal trunking on commercial and non-domestic public sector buildings.

Plastic products – included here are offcuts of building services products such as PVC or PE pipework, electrical cabling and cutting. On some applications, the level of arisings can be quite high. However, except for volumetric modular building systems, substitution of other types of MMC would have little impact on reducing waste levels. The other main type of plastic waste is that of offcuts from sheets of membrane e.g. waterproofing for roofs and dampcoursing.

Ceramics – most ceramic waste is broken bathroom and kitchen tiles, which can be reduced through the substitution of bathroom and kitchen pods.

Dry concrete products – the range of waste arisings is typically between 2 –12%, although this wide difference is largely down to definition. At the higher end of the range, waste block material is sometimes included. However, where a large amount of pre-cast components such as paving, kerbing etc are used, waste arisings can be notable.

2.3 Key Sources of Waste Arisings By Application

2.3.1 Introduction

In order to develop a shortlist of MMC products that could help reduce site waste levels over the short to medium term, it is necessary to identify the particular applications that typically generate large volumes of waste. However, this is proving difficult to obtain any hard data for as even the more environmentally progressive house builders and contractors have only relatively recently began collating data on material waste.

However, as in the previous section, there are a reasonable number of case studies to show that the main traditional construction processes generating the highest levels of waste are:

- Roof construction
- External walls construction
- Ground floor construction
- Internal fit-out

2.3.2 Roofing

Table 11: Key Traditionally Built Roof Applications Generating Waste

Building application	End-use	Types of scheme	Materials
Pitched roofing	Houses, apartment blocks, various non-residential	Newbuild – small-medium size, bespoke Refurbishment	Timber offcuts from battens, purlins, rafters and joists Offcuts from sheet materials – insulation, waterproofing, sarking etc Cardboard boxes for roof tiles Shrinkwrap for insulation rolls & sheets Plastic packaging for sheet products Broken tiles
Flat roofing	Apartments & non-domestic	Newbuild Refurbishment	Offcuts from sheet materials – mainly plastic waterproofing membranes Plastic packaging for sheet membranes
Porch roofing & canopies	Houses	Newbuild	Broken tiles

Source: AMA Research/trade sources

Among the key product/material waste streams generated by both pitched and flat roofing construction is that of membranes, including bitumen rolls, sarking and. On larger standardised flat roof developments, waste from membranes is around 5%, all of which currently goes into landfill. On more complex roofs that require more cutting around upstands and rooflights, the proportion of waste material can be as high as 15%.

Other key waste materials include insulation. On pitched roofing, an estimated 3 - 5% of fibreglass and rockwool insulation material is discarded as waste.

On traditionally built medium-higher volume housing newbuild developments, pre-fabricated trussed rafters are now used as standard, as they save considerable installation time and costs and are economic when procured in bulk. However, on small-medium housing developments and bespoke newbuild, there is a much higher level of on-site construction of the timber roofing elements. This typically requires the sawing to length of battens, rafters, trusses and purlins, which generates significant amounts of offcuts waste.

The construction of porches on private housing can also be quite wasteful, the main waste arisings typically being broken roof tiles.

2.3.3 Flooring

Table 12: Key Traditionally Built Floor Applications Generating Waste			
Building application	End-use	Types of scheme	Materials
Ground floor	All	Newbuild	Formwork used for ready mix concrete or blockwork Offcuts from sheet & polystyrene insulation
		New build Refurbishment	Offcuts from sheet floorcoverings; offcuts from timber floor panels: offcuts from vinyl & carpet sheet flooring; unused carpet, ceramic and vinyl floor tiles
Other floor levels	All	New build Refurbishment	Offcuts from sheet floorcoverings; offcuts from timber floor panels: offcuts from vinyl & carpet sheet flooring; unused carpet, ceramic and vinyl floor tiles
Source: AMA Research/trade sources			

Waste material arises from the installation of the floor beams and ground floor insulation and from the installation floorcoverings and the associated packaging waste.

Traditional in-situ methods of floor construction include the laying of concrete slabs, readymix concrete and timber beams with wood panel flooring. Concrete slabs and readymix concrete require substantial amounts of formwork and propping that need to remain in place until the concrete has matured. The formwork is then subsequently skipped and sent to landfill.

Timber beams and wooden floor panels installed in-situ typically require sawing and so generate offcuts waste and waste material in the form of unused lengths and elements of packaging.

With floor coverings, the use of packaging is considerable.

- Carpet rolls, linoleum rolls and vinyl rolls are delivered with packaging including a so-called “cardboard roll” which prevents damage by preventing collapse during transit. These products are further protected from possible damage by being wrapped in LDPE (Low Density Polyethylene) plastic film, onto which a paper label is fitted to identify the manufacturer, colour, pattern, size etc.
- Carpet tiles, ceramic tiles, linoleum and vinyl tiles are usually supplied in cardboard boxes, which are stacked onto wooden pallets, which are often shrink-wrapped for transportation.
- Laminate flooring is usually supplied in cardboard boxes, which are shrink-wrapped to protect the contents.

In terms of material waste, there are unused tiles and there are offcuts from rolled materials. Being flat and lightweight, these account for a lower proportion average skip content than other materials, but nearly all of these waste materials are landfilled.

2.3.4 External Walls

Table 13: Key Traditionally Built External Wall Applications Generating Waste

Building application	End-use	Types of scheme	Waste materials
Inner leaf	Mostly housing, some non-housing up to 3 storeys	Brick & block newbuild	Broken and unused blocks Unused mortar Cavity wall insulation offcuts Pallets used for blocks Shrinkwrap used for blocks and insulation
	Mostly 4+ storeys	Steel/concrete frame & blockwork newbuild	Pallets used for blocks Shrinkwrap used for blocks and insulation Light steel frame offcuts or plywood shuttering for pre-cast columns
Cladding	Mostly housing, some non-housing	Brick & block newbuild	Broken clay bricks Unused mortar Pallets used for bricks Shrinkwrap used for bricks
	Mostly 3+ storeys	Steel/concrete frame & blockwork newbuild	External insulation panels offcuts Pallets used for insulation panels Pallets for cladding facings Shrinkwrap used for insulation panels Cardboard used for cladding fixings Unused render

Source: AMA Research/trade sources

On traditional brick and block construction of external walls on houses and other buildings typically no higher than 3 storeys, the main sources of waste are broken and unused aircrete blocks and the associated packaging, in particular non-returnable pallets. Broken bricks can constitute a significant waste stream, but most unused bricks are recovered for re-use or recycling.

Most commercial and public sector accommodation buildings are built using either steel or concrete for the main structural framework. Typically, blockwork is not used for the inner leaf, although some structures do combine both but generally it is impractical to use blocks on buildings over 2 storeys. The specification of site-assembled light steel framing systems is now commonplace on buildings of 3 - 8 storeys. As ‘stick’ systems are supplied in standard lengths they need cutting to length.

In-situ cladding and render systems used on buildings of 3+ storeys typically generate relatively high volumes of insulation waste in the form of insulation board offcuts. Delivery to site also requires extensive use of pallets and shrinkwrap. With regard to the façade finish, waste levels vary depending on size and type. Typically curtain wall systems are highly specific and being costly, waste levels tend to be minimal, though standard windows and doors are usually delivered to site in shrinkwrap.

2.3.5 Internal fit-out

Table 14: Key Traditional Internal Fit Out Applications Generating Waste

Building application	End-use	Types of scheme	Waste materials
Internal walls & party walls	All accommodation	Newbuild	Plasterboard – offcuts, damaged Unused plaster Pallets & shrinkwrap for plasterboard Used paint tins, roller sets Studwork (party walls) – offcuts, damaged
		Newbuild Refurbishment	Unused plaster Used paint tins, roller sets
Internal windows	Residential	Newbuild Refurbishment	Used mastic gun cartridges Unused putties
Mouldings	All accommodation	Newbuild	Offcuts – mostly for skirting boards
Fitted kitchens	Residential	Newbuild Refurbishment	Rework – whole units Kitchen worktops offcuts Pallets, cardboard, polystyrene protection, plastic bags for fittings & shrinkwrap Floorcoverings & packaging Broken & unused tiles
Fitted bathrooms	Residential	Newbuild Refurbishment	Pallets, cardboard, polystyrene protection, plastic bags for fittings & shrinkwrap Floorcoverings & packaging Used mastic gun cartridges Broken & unused tiles
Internal doorsets	Residential Other accommodation	Newbuild Refurbishment	Cardboard, shrinkwrap and paper
Heating & lighting equipment	All	Mostly new build Some refurb	Pallets, cardboard, polystyrene protection, plastic bags for fittings & shrinkwrap
Building services	All	Newbuild Refurbishment	Offcuts/unused lengths from pipework, cabling, cable trays & ducting Shrinkwrap, plastic bags, paper bags and carboard boxes for fittings

Source: AMA Research/trade sources

As the table above indicates, discarded packaging is the main waste arising from internal fit-out works whether on newbuild schemes or refurbishment. Waste from installation work is mostly generated by the fitting plasterboard and plastering the structural internal walls and the party walls and the installation of fitted kitchens

3.0 MMC Product Review

3.1 Introduction

In selecting MMC products for review, the following factors have been taken into consideration:

- The main construction waste streams and the application from which they mainly arise e.g. packaging from roof tile installation, cement from plastering.
- The size of existing application sectors e.g. commercial roofing, cladding and structural elements, and opportunities to increase MMC product penetration into these sectors e.g.: commercial roofing and the increased use of composite roof panels.
- The availability of MMC alternatives.
- The current size and potential growth for MMC products, e.g.: timber frame housing.

To date, the MMC product groups that we have identified as offering possible solutions to reducing waste levels on construction sites over the short to medium term are summarised below:

1. **Volumetric modular** – we consider this a key MMC technology for inclusion on the grounds that it substitutes several on-site product applications that typically generate significant waste volumes. These include roof and external wall insulation, roof tiling, brick & blockwork, drylining, on-site cladding and all associated packaging. The technology is well established and there are new developments in high-volume production, notably at Corus' Deeside factory.
2. **Timber frame and steel frame flat packs** – these are mainly used in housing and are mainly displacing the use of concrete blockwork used for the construction of external wall inner leafs and party walls. The other reasons for including timber frame systems is that demand is growing fast, underpinned by housing shortages in parts of the country, with public sector specification an important influence on demand.
3. **Prefabricated kitchen & bathroom pods** – this is a growing market, underpinned by demand in fast growing sectors of the single living accommodation (SLA) market which includes MoD garrisons, student residences, Key Worker Living and high-rise apartment blocks. Key waste streams that are likely to be reduced using pods include those generated through the interior fit-out of kitchens and bathrooms, plumbing offcuts, and cement and plaster.
4. **Composite/insulated/sandwich (non load-bearing) panels** used for walls and roofing. These are mostly profiled steel products used on commercial and industrial applications, although there are newer products made from other materials such as concrete and GRP suitable for residential use. Although current uptake levels of steel profiled composite panels are quite high, market penetration at c. 35% is still way below the maximum of 90-100%. It is likely that they will further displace site-assembled twin wall systems, while energy saving regulations will lead to a phasing out of single skin steel cladding on many applications. The main waste generated from on-site assembly of twin-wall systems is waste insulation material. Roof panel systems that arrive on site with simulated tile effects could lead to a reduction in tile offcuts and packaging waste.
5. **Light steel frame (LSF) systems** are one of the more recent developments in MMC, used for building façade construction. Closed frame systems are currently only supplied by Kingspan Offsite. Although uptake levels are currently low, there is considerable potential to displace on-site cladding/façade installation. A high level of uptake could, in theory, lead to lower levels of site-generated waste from insulation, drylining and cladding material offcuts.
6. **Pre-cast structural panels -** external and party wall panels increasingly being supplied as part of panellised building systems in conjunction with floor components and other components such as pre-cast staircases, basement units and roofing.
7. **Pre-cast hollow-core flooring** - there are indications of an increase in the specification of hollow-core flooring on ground floors and second floors on residential and commercial applications, in

substitution for in-situ concrete flooring and timber flooring. In-situ concrete flooring typically requires a large amount of formwork, while in-situ timber flooring generates packaging waste and offcuts material.

8. **Structural insulated panels (SIPS)** – while the use of SIPS has been well established in the US, their use in the UK has, to date, largely been restricted to social housing. These differ from composite panels in that they are load-bearing. Their increased use would displace traditional construction methods and the associated waste, notably insulation materials, brick and blockwork. A key barrier to a substantial increase in use over a short period is the low UK manufacturing capacity.
9. **Pre-cast concrete cladding** is typically manufactured, supplied and installed under bespoke supply and fix contracts. They are high-value products designed for prestigious buildings such as acute hospitals, corporate headquarters, government buildings, large-scale shopping malls.
10. **Tunnel form construction** is a system new to the UK but is well established in several other Western European countries. Although it is not an MMC product it is recognised as one of the most significant of the new MMC.
11. **Insulating concrete formwork** is a factory made formwork system comprising twin-wall expanded polystyrene (EPS) blocks or panels, which are assembled to create the external walls of a building. Ready mix concrete is subsequently poured into the gaps. The EPS remains in place to act as the external wall insulation. This is a relatively new system to the UK market but it has been used on housing

We have researched the following product groups and, for the reasons stated below, do not consider them relevant to this study.

1. **Large pre-assembled sections of steelwork** – steel frames used for structural purposes are already used extensively on industrial buildings and commercial buildings up to two storeys. There are applications where concrete is considered more suitable, such as wide-span structures and buildings of 8+storeys. Steel is not a substitute here. Furthermore, macro-economic factors such as rising global steel prices have recently led to an increase in the use of concrete over steel. Although pre-assembled beams are used as an alternative to standard hot rolled steel columns and beams, we assume that the intrinsic nature of steel means that it cannot be made to measure on-site. Previous research into scrap steel has shown that nearly all of it is 'process waste' and end-of-life products. There are no indications of any waste generated on construction projects.
2. The same applies to **pre-assembled bridges** and other pre-assembled civils structures.
3. **Unitised curtain wall & cladding** – in 2004 and 2005 some 3m sq m of curtain wall was installed, most of which was either bespoke – and undertaken by European contractors - or system-based. On bespoke projects and in the use of curtain wall systems, profiles and sheets of glass are typically made-to-measure before delivery on site. Therefore, the amounts of waste generated from installation are generally very small. What waste there is will usually be damaged or badly cut glass, unused sealant and gasket offcuts. The amount of packaging varies depending on manufacturer location. Typically, with bespoke systems imported from Europe, there will be a high level of packaging used to protect glass sheets and the finish on the profiles. With UK fabricators, glass is often supplied to site on stillages or in crates with a minimum of packaging. Unitised curtain wall, and cladding, is typically more costly than site-assembled systems and as such is mostly used on higher-end applications. Site-assembled systems are used extensively at the lower-end of market applications. Consequently, it is highly unlikely there will be any significant shift towards unitised products on applications such as shopfronts, out-of-town sites, car showrooms etc.
4. **Trussed rafters –** although trussed rafters are a prefabricated alternative to the on-site fabrication and installation of purlins, trusses, rafters and joists they are generally not considered to be a form of MMC. This is mainly because they are well established and accepted technology and are widely specified for use on large-scale housing newbuild developments. However, they are not always suitable for bespoke designs and small developments, mainly due to costs.
5. **Pre-assembled doorsets** – typically on newbuild installations there is minimal waste generated on the in-situ installation of doorframes as they are made to measure. The use of pre-assembled doorsets is being driven solely by timesaving considerations. On replacement door installations there are higher levels of offcuts waste, but due to the very fragmented nature of the replacement door market, waste collection is extremely difficult and unlikely to be cost efficient.

6. **Pre-assembled building services systems** – although these are becoming increasingly popular, the main reason for this lies with the shortage of skilled electricians and mechanical engineers and the need for ever-faster installation. Although the volume of waste generated from the installation of plastic pipework, ducting and cabling can be significant, the substitution of modular for site-built systems generates only limited waste savings.
7. **Pre-cast and other pre-assembled inspection chambers** – from our understanding this is both a niche market and one where the use of pre-cast units has become standard, with site-built brick inspection chambers now relatively uncommon.
8. **Pre-cast piling** - there is reportedly little wet concrete overburden nor excavation waste arising from in-situ piling, mainly due to made-to-measure specifications. Because every construction site is unique – in terms of soil type, required piling methods and depths etc – it is impossible to compare pre-cast and steel piling with in-situ techniques.
9. **Pre-cast foundations** – while conventional shallow foundation systems require casting on site, there is typically very little waste. What overburden there is normally returned to the factory.

3.2 MMC Market Overview

This section provides a broad overview of key product sectors, market size estimates, trends etc. Most of the following information has been gathered from existing AMA research into MMC products, supplemented by other sources where possible.

The main issue with estimating market size relates to definitions, whether they refer to MMC in general or, more particularly offsite manufacturing. Several reports have been published which provide a range of market estimates, typically ranging from £1bn to £2.2bn. Therefore, the data below should be treated as indications of relative magnitude rather than of actual market sizes.

Table 15: UK Market for MMC Products 2005

	Approximate Value £m
Panellised modular building systems	620
Timber frame	475
Steel frame	30
OSB structural insulated panels (SIPS)	35
Pre-cast concrete panels/cross-wall construction	80
Permanent volumetric modular building systems	200
Building envelope components	465
Composite/sandwich panels	345
Pre-cast concrete cladding panels	70
Light gauge steel framing systems	50
Building services systems incl. modular plant rooms	200
Kitchen and bathroom pods	125
Pre-cast concrete structural products	110
Insulating concrete formwork	20
Bridges	40
TOTAL	1,780

Source: AMA Research/trade estimates

Notes to the table

** there is a small element of double counting as pre-cast concrete pods are included in the estimates for both kitchen & bathroom pods and pre-cast concrete structural products*

*** not included here is tunnel form construction as it is a site-built form of MMC with values typically given at installation prices. In 2005, it is estimated that the market was worth around £130m*

3.3 Volumetric Modular Buildings

3.3.1 Definition

Pre-assembled volumetric modular buildings are defined as including off-site manufactured fully assembled 3-dimensional units, or modules, which are either used as 'standalone' units or are combined, by linking on-site, to form a complex of units, or alternatively to form a modular building, consisting of several linked and stacked units or modules with appropriate cladding features. Volumetric modules may be stacked several storeys high dependant upon module construction and the need for additional structural elements, etc.

However, the focus of this section of the report is only on volumetric modules used for constructing permanent and long-term temporary buildings (15 years). Excluded from our definition are: accommodation units typically used at construction sites, hire units, refurbished/second hand modules, garage batteries, portable toilets, anti-vandal units, jackleg cabins, agricultural buildings, plant & pump rooms.

3.3.2 Market size & trends

The UK volumetric prefabricated buildings market has experienced a period of significant expansion with the total market in 2005 estimated at over £500m at manufacturers sales prices. However, the majority of prefabricated volumetric buildings comprise steel cabins and accommodation units and other units for hire. We estimate that the permanent modular building sector has a value of around £200m at manufacturers sales prices. However, it has to be noted that it is very difficult to determine what constitutes 'permanent' and whether long-term temporary should be included or excluded from the estimate. There is a significant level of usage of volumetric units on a long-term temporary basis, which can be as long as 15 years, although numbers are extremely difficult to quantify.

Assuming an average price per module of around £12,000, this equates to around 16 –17,000 modules. This is likely to increase by at least 1,500 –2,000 units in each of 2006 and 2007 as construction under the MoD's Project Allenby/Connaught scheme gets underway this year.

In overall terms, there is strong underlying growth in the volumetric buildings sector, driven by a range of factors including:

- Underlying growth in construction orders in key end use sectors for volumetric buildings, e.g.: health, education, defence, hotels, etc.
- Trends towards single living accommodation requiring more cellular volumetric accommodation blocks.
- Strong growth in sectors where high repeatability of design required (student, MOD accommodation)
- Importance of speed in construction programmes in some sectors, e.g.: hotels, fast food outlets to generate revenue.
- The shortage of skilled construction personnel, and increasing emphasis on safety, represent key motivating factors for prefabricated structures in general, reducing the time spent '*working at height*'.
- The urgent requirement for affordable rented key workers accommodation in the health and education sectors is benefiting pre-fabricated volumetric buildings.
- Availability of flexible financial and design/installation package options from some manufacturers of volumetric buildings.

Key drivers for growth of volumetric buildings are relative cost of construction, high repeatability of units, importance of speed of installation/build programme, site conditions, skills shortages, H & S issues etc. Attitudes and perceptions of specifiers also represent a major barrier in some key sectors. It is important to emphasise that waste reduction is not currently considered to be a key factor influencing demand for volumetric structures.

3.3.3 Product mix

The market for volumetric modular buildings has tended to be project driven. The majority of installations have been bespoke, undertaken on a design & build basis by the manufacturers themselves, though there are some exceptions.

3.3.4 End-use market mix

Key end use sectors for permanent prefabricated volumetric buildings include the following:

Residential

- Residential park homes and leisure homes
- Social housing
- Key Worker Living accommodation
- Student single living accommodation
- MoD single living accommodation

Commercial and Industrial

- Offices – mainly back offices and business park developments
- Stand-alone convenience stores and out-of-town stand-alone fast food outlets

Leisure

- Branded budget hotels – entire stand-alone buildings
- Branded 3 -5 star hotels – mainly extensions
- Sports changing rooms and shower/washroom facilities
- Stand-alone gymnasiums/fitness clubs
- Sports pavilions – entire stand-alone buildings

Education

- Nurseries – entire stand-alone buildings
- Secondary school classrooms – extensions and stand-alone units
- Tutorial blocks – entire stand-alone buildings at higher education establishments

Healthcare

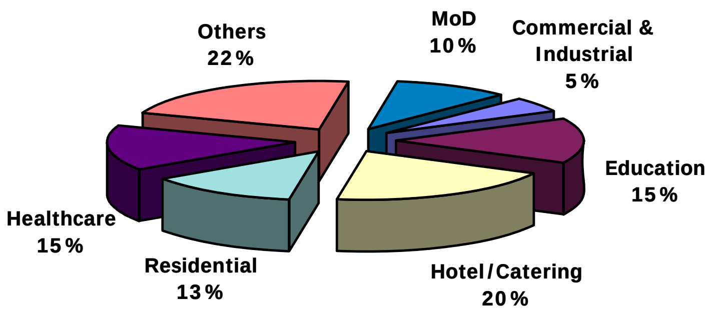
- Nursing homes, care homes – extensions and stand-alone buildings
- GP Surgeries – entire stand-alone buildings
- Health/walk-in/treatment centres - entire stand-alone buildings
- General/acute and district/community hospitals – ward extensions, operating theatres

Custodial

- Prisons and YOIs – mainly stand-alone cell blocks
- Immigration/detention centres – stand-alone accommodation blocks.

The above list is not exhaustive but indicates the wide range of uses for prefabricated volumetric buildings. As indicated earlier, the UK market for permanent volumetric prefabricated buildings is estimated to be worth £200m at manufacturers sales prices in 2005. The following chart indicates our estimates of mix of sales to major end user areas of application: -

Chart 16: Mix of Sales of Permanent Volumetric Buildings to Major End User Sectors by Value (2005)



Source: AMA Research/trade estimates

The mix of sales to major end use sectors is difficult to estimate due to overlap - for example, we have classified student accommodation as 'residential', but it might also be included under 'education'.

In the schools, healthcare and commercial/industrial sectors, there is a high level of usage of both short-term hiring and long-term leasing of volumetric modules. For the purpose of our estimates in the above chart, we have attempted to exclude them.

'Others' includes applications such as airport terminal buildings, sports pavilions and changing room/shower units, care homes, prison cell blocks and immigration & detention centres. In this latter sector has been one of the largest developments constructed from volumetric units, the Harmondsworth Immigration Centre.

As the estimates are for 2005, this above chart does not reflect the recent massive investment in MoD single living accommodation. From 2006 through to 2012, we expect there to be a significant increase in MMC usage and therefore the MoD's end-user market share will increase markedly.

3.3.5 Market potential for reducing site waste

From 2006-2008, the overall market is forecast to continue to grow at a rate of around 10 - 15% p.a., reflecting further growth in a range of end-use sectors, including single living/cellular accommodation, health, education, MoD, hotel/leisure, etc.

Between 2008 and 2011, growth in the market is likely to accelerate further with the construction of the apartment complex in the Olympic Village, and further success is dependent on wider market acceptance as indicated previously. However, there are barriers that may affect the volumetric buildings market over the medium term:

- Prospects for the take-up of volumetric housing by housebuilders is difficult to forecast given the competing interests of other MMC systems (timber, steel), concrete, or traditional masonry systems.
- Continuing uncertainty as to whether homeowners' preferences can be changed from brick and masonry to prefabricated systems (image issues).
- There is still a widely held perception among architects and other specifiers that volumetric construction is best suited for developments where there are high levels of repeatability in terms of both façade features and in the types of buildings being used. There is still a reluctance to consider them on bespoke architectural schemes.
- There is still a perception among many architects and other specifiers that the quality of modular construction is inferior to other methods of construction.

- There is a perception among architects and designers that a significant increase in demand for modular construction could jeopardise their own work.

However, in spite of these barriers the main factors that are likely to accelerate demand for volumetric modular construction is the requirement for fast-track construction and the need to minimise site hazards, particularly in:

- Those end-use sectors where clients need to build new facilities as quickly as possible to start generating early revenues e.g. retail, hotels, private-owned student accommodation.
- Those end-use sectors, where current supply levels fall short of demand e.g. affordable housing, student accommodation, primary healthcare centres.
- Those end-use sectors where there is a need to minimise disruption to clients' day-to-day operations e.g. healthcare premises, educational establishments, military sites etc.

However, none of our respondents to this survey indicated that they either marketed or specified modular construction as a means of reducing construction site wastes.

There are very few case studies identifying waste savings where volumetric systems are substituted for traditional building methods. This is mostly because, to date, the vast majority of installations have been undertaken under supply and fix contracts by the manufacturers themselves. There have been very few projects where volumetric buildings have been supplied on a third party basis. Furthermore, most volumetric buildings have been supplied as bespoke designs on relatively low-volume applications such as hospital extensions, hotel extensions, classrooms, stand-alone units etc.

However, where volumetric construction is substituted for traditional methods there are key areas of applications where site waste can be eliminated: -

- Plasterboard for internal walls
- Aircrete and lightweight blocks used for the inner leaf on external walls
- Brickwork and other cladding materials
- Mortars, plaster and cement
- Paints - optional
- Insulation for cavity walls, flooring and roofing
- Structural timbers
- Floors and floorcoverings
- Associated packaging materials
- Concrete components other than blocks

The manufacture of volumetric modules is akin to car assembly in that by its very nature, volumetric module assembly is a highly standardised process, where modules are built to standard specifications from pre-fabricated and made-to-measure components and materials. Waste from offcuts is minimal.

A key advantage with modular construction is that all materials used in the manufacture of modules are kept in covered storage, and so there is no loss due to damage arisings from the elements, accident, carelessness etc, that are often the cause of much site waste.

Most modules are steel-framed and with permanent units, product lifespan is typically around 60 years. A small proportion of modules are made from timber and typically are only designed for the shorter term, at around 10 years or until the timber starts to rot.

With volumetric and panellised steel modular units, the wall and roof frames are typically constructed using the stud and track method of connection, whereby cold rolled galvanised 'C' steel profiled sections are joined together using self-drill/tap fasteners, bolts and rivets. Consequently, at the end of life, these should be easy to disassemble. The floor and ceiling joists have service highways in the form of holes that allow for the running of cables and pipework, which allow for ease of removal. With the façade and roof covering elements, the façade panels, insulation boards and drylining are all connected using a system of brackets, rails and self-drill/tap fasteners. As no mortar, is used, disassembly of these components should be straightforward.

The steel components are all highly recyclable and are metal facade materials such as aluminium, and zinc and also brick slips, timber and slates. However, whether facing materials such as high-pressure laminates, GRP and terracotta will be recyclable in another 50 - 60 years time is open to question.

Refurbishing volumetric and panellised modules is quite a significant business in its own right. In the UK, there are several suppliers that specialise in restoring end-of–life modules for reuse.

3.4 Panellised Modular Building Systems

3.4.1 Definitions

Within the context of this report we have defined panellised modular building systems as building systems that are delivered in flat-pack format to site where upon panels are craned into place. Under this heading we have included 4 main types of panellised building system

- Timber frame
- Steel frame
- Wood based structural insulated panel systems (SIPS) & structural insulated roofing panels (SIRPs)
- Concrete and cement structural panel systems (cross-wall)

The key features these building systems have in common include:

- External wall and roofing frames/panels are factory-assembled although the degree to which other components - e.g. internal wall plastering, insulation and cladding - are factory-fitted vary.
- They form part of a building's structure, i.e. they are load-bearing, although they do often also form part of the envelope. However, many products are flexible to the extent that they can be used as non-load-bearing applications. For example OSB SIP panels can be used as cladding on timber frames structures and light steel open frames can be used as non-load-bearing infill panels
- These frames and panels are typically delivered to site in 'flat-pack' format, where they are subsequently lifted straight into position onto the foundations.

Timber frame systems are by far the most established of the four systems we have identified and as such are the most commonly specified, mostly for housing and to a lesser extent on high-rise apartment blocks and low-rise commercial applications.

The degree of pre-fabrication varies throughout the timber frame industry. The most commonly specified systems are open-frame comprising softwood vertical studs and horizontal rails, trussed rafters, wood-based panel sheathing, plasterboard lining and an external breather membrane. Ground floors can be of concrete or timber. Intermediate floors are of timber joists or prefabricated panels. Thermal insulation, internal vapour control membrane and lining are all installed on site.

Closed panel systems comprise the same components used with open frame systems but the addition of pre-installed insulation, protective membranes, linings and external joinery. Some top-end of the market systems also include the buildings services elements.

The studs carry vertical loads through the structure and transfer them to the foundations. The sheathing provides resistance to lateral wind loads. At openings, e.g. doors and windows, the vertical loads are carried by timber lintels over the opening and through additional supports, known as cripple studs at each end of the lintel. The outer cladding provides decoration and weather protection.

Steel frame panellised building systems - these also mostly used for housing but are generally supplied to site as warm frame construction panels with insulation elements factory fitted. Steel frame systems typically comprise insulated external wall panels, party walls, flooring with some suppliers offering a roofing option. Some systems are also supplied fitted with external wall cladding, mostly brick slips. Within the context of this report, we differentiate between steel frame modular building systems and light steel framing (LSF) systems used in the construction of volumetric modules or for cladding support.

Wood-based structural insulated panel systems (SIPS) and structural insulated roofing panels (SIRPs) - for convenience we included SIPS and SIRPs together. SIPS are typically made from oriented strand board (OSB) and have been used in the US construction market for around 60 years. SIPS are essentially panels usually consisting of an insulating expanded (or extruded) polystyrene core (alternatively polyurethane), laminated between two sheets of OSB or plywood. In structural terms, manufactured panels function as an 'I'-section beam, where the insulating core acts as a 'web' and the two connected outer sheets or OSB act as 'flanges'. SIPS are mainly used for the external walls, roofs, floors, party walls and roofing, the key end-use applications, to date, being social and private housing, and to a lesser extent commercial buildings and apartments, generally up to 4 storeys high. SIPS can also be used on non-structural applications such as infill panels and as overcladding on existing buildings.

Currently the use of SIRPs has largely been limited to the *Unipur Structural Insulated Roofing System*, which is manufactured by Unilin in Belgium and supplied by Milbank Roofs. *Unipur* comprises structural insulated panels consisting of 3 or 4 integral timber rafters fixed to and stabilised by a rigid facing board which also forms the ceiling finish and between each rafter is a layer of polyurethane foam. There is a wide range of roof covering options.

Pre-cast panel systems – this is a term used here to cover a range of structural pre-cast concrete panel systems, which are now increasingly being supplied as panellised building systems, the key areas of application being the external walls, party walls and sometimes the basement walls. There are a number of proprietary systems now available. Some of these are centred on insulated panels while others are largely based on cross-wall technology. The following definition taken from the Concrete Centre's website offers a description:

'Where buildings are designed with a cellular structure - for example multi-storey hotels, prisons or accommodation blocks - the use of cross-wall pre-cast concrete construction provides the benefits of speed and on-site productivity. It doesn't require extensive deployment of site labour and avoids the volume of loose materials required for traditional masonry construction and their inherent handling problems.

The components - floors and load-bearing walls, with pre-formed window apertures - combine swiftly to form room shells. Concrete finishes to walls and soffits are of good quality as a result of their production in steel moulds and enable minimum plastering or finishing with directly applied coatings'.

3.4.2 Timber frame

Market size

There are two distinct markets for timber frame systems - the residential sector and non-domestic applications. The latter includes a range of building types including sports pavilions, stand-along 1-2 storey office units and visitor centres at tourist attractions. The Timber Frame Association estimates that in 2005, the market was worth over £475m at manufacturers sales prices. By far the largest and most high profile sector is that of housing.

The market for timber frame housing itself s split between the self build sector, where kit packages have been a popular method of construction for decades, and the private and social housing newbuild sectors where timber frame's popularity in England has started to accelerate only over the last few years.

Within the UK new housing market, timber frame accounts for around 34,000 units across the private and social housebuilding sectors. According to trade sources, the self-build sector accounts for a further 3,000 timber frame houses. Although the use of timber frame in the UK is low compared to other major countries, its market share of housing starts in all sectors in the 6-year period to 2005 has more than doubled from 7% to 16%.

Product mix

The volume of timber frame apartment blocks constructed in the UK has risen considerably since 2000. The majority of this growth has been in England and is a result of the need to build at higher densities because of land price and availability. Over the period 2000 – 2005 there was an increase from around 2,300 units to over 10,000 units. Around 70% flats built using timber frame having been within the 1-3 storey range with the remaining 30% being 4+ storeys. Since 2000, timber frame has taken share away from brick and block construction within the 1-3 storey market, with the latter's share having been cut from 95% to around 85%.

The volume of detached units has generally remained relatively static fluctuating slightly between 1,700 and 1,900 units p.a.

'Other' types of timber frame housing have increased in number from around 2,600 to around 6,000 over the period 2000 – 2005.

In Scotland, where the need to build at higher densities is not as critical as, for example London or the South East, detached houses are more popular and in volume terms are constructed at more than double the rate of flats.

End-use market mix

The private housebuilding sector is the largest area of demand for timber frame, accounting for an estimated 73%, with social housing at 18% and the self build market at an estimated 9%, though share is declining. All of the UK housebuilding sectors - private, social and self build - have seen growth in timber frame housing, which has increased market share over traditional brick and block construction due mainly to the political drive to increase the use of modern methods of construction, primarily through MMC.

Market potential for reducing site waste

The increased use of timber frame building systems, in substitution for brick and block construction, could have a significant impact on reducing waste levels from certain applications. This is largely because:

- Timber frame is an established and proven technology with low barriers to specification
- Timber frame manufacturing capacity is large and continuing to expand

The strongest growth rates are forecast in the affordable housing sector, a combination of social housing for rent and government subsidised housing for part ownership. Over the medium-longer term, the key drivers should be:

- Overall increase in housebuilding activity to meet demand.
- Industry acceptance of MMC.
- Level of acceptance of timber frame compared to steel and concrete where MMC is selected (cost/design issues).

When asked what they consider the main barriers to the increased uptake of timber frame, our respondents from among the manufacturers were that:

- There is still a significant level of negative perception about the quality of timber frame in certain key sectors including private housebuilding, student accommodation.
- The traditional construction lobby in England is very powerful and includes organisations such as the Traditional Housing Bureau.

Although the market for timber frame is expected to continue growing, it is debatable as to what extent they can contribute significantly towards reducing site waste when substituted for traditional brick and block construction.

The main obvious saving is that they displace the need for inner leaf block construction and the waste associated with this, i.e. broken and discarded blocks and unused mortar and the associated packaging. Where pre-fitted with plasterboard there are also apparent waste savings compared to the in-situ installation of plasterboard. However, when we asked respondents from several leading housebuilders about their experiences with timber frame, replies were mixed and therefore inconclusive.

A few timber frame manufacturers do feature waste reduction in their marketing, but most do not, focusing instead on the time saving aspects and the use of wood from sustainable managed woodlands.

Systems supplied into the housebuilding sector typically have a lifespan up to 60 years. The ease with which timber frame systems can be disassembled depends on the type of fastening methods. At the end of a building's life, there should be significant opportunities for recovering timber components as these - i.e. studs, rails, I-beams, trussed rafters and floor cassettes - can be disassembled relatively easily. However, the panels –made from OSB, particleboard etc – using for floor cassettes are typically attached to the joists using automated nail guns. This might be more difficult to take apart. The main issue determining the ease with which to recycle timber components largely depends to the types of wood treatments originally used, as these affect recycling applications. For example, many existing biomass and conventional coal-burning plants cannot burn treated timber due to factors such as harmful emissions and damage to boilers.

3.4.3 Steel frame panellised building systems

Market size and trends

Light steel panellised building systems are a relatively newer development than timber frame systems and as such command a smaller share of the newbuild market. Because some suppliers of panellised modular systems also supply volumetric building systems, it is difficult to arrive at an accurate market size. However, we consider that it lies somewhere in the range of £25m - 35m at manufacturers sales prices.

It appears that by far the largest application for these systems is the housing sector, where there several manufacturers solely focused on supplying housing systems.

Steel frame construction accounts for approximately 2,000 – 3,000 housing units per year although we understand there is enough spare capacity to produce between 5,000 – 8,000 units should there be the demand for that type of construction.

End-use market mix

The main application for steel panellised building systems is the housing sector, where there are companies specifically targeting this particular market. These include Fusion Build, Advance Housing and Framing Solutions.

Market potential for reducing site waste

Where steel frame systems are substituted for traditionally constructed buildings, the main areas of waste reduction would be through the elimination of inner leaf blockwork, cavity wall insulation, plasterboard and the associated packaging arising from transportation, site storage and installation.

However, these savings would need to be offset against any packaging waste used for the panels. However, none of our respondents were able to offer any information in this regard, except for our respondent from Redrow who intimated that the level of waste reduction had not always been significant.

Consequently, we cannot say with any certainty that panellised steel housing systems do contribute towards a net reduction in waste levels compared to brick and block construction.

However, a key advantage with steel frame systems over other types of house construction, including timber frame, is that at the end of their life-spans, they can easily be disassembled and the steel frames can be recovered for re-processing, which would significantly reduce end-of-life waste.

3.4.4 Structural insulated panel systems (SIPS) & structural insulated roof panels (SIRPs)

Market size & trends

The market for SIPS is estimated at around £30 –35m at manufacturers sales prices in 2005. However, for 2006 the market value will be much higher due to the installation of SIPS on a massive social housing scheme in Manchester.

Although applications are varied, the main market driver behind SIPS is growth in the social housing sector and growth in the self-build market. The market for SIRPs is currently very small, estimated at around £0.6 – 0.8m. However, since 2003, when the first system was introduced to the UK, it has grown four-fold.

Historically, the main barriers to growth to the uptake of SIPS have been:

- Actual cost of manufacturing and installing SIPS buildings and SIRPs compared to high volume production open timber frame buildings This has particularly been the case in certain geographical markets where timber frame is a well established and common building method, most notably in Scotland.
- A lack of experience among specifiers and contractors and thus an unwillingness to 'experiment' with new technologies.
- High installation costs being charged by independent third party contractors.

Recently, many of the barriers that had impeded market growth have been lowered or removed. For instance, there are now many examples of SIPS built houses and non-residential buildings that show SIPS to be a proven technology in the UK, even though SIPS has been a standard building product in the US for over half a century.

Confidence in SIPS and SIRPs among clients and specifiers is also being bolstered by the recent award of BBA, BRE or British Standard certification to several products on the market.

Where some third party installation companies had been over-pricing contracts, this has recently been resolved by a some suppliers getting more actively involved in the installation process and in doing so have been able to reduce installation costs.

The other key driver has been the general increase in interest in MMC technology and demand among client organisations and specifers within the public sector, and most specifically the social housing market, where there is now an emphasis on developing fast-track affordable housing.

Product mix

Most SIPS are bespoke products that can range from basic systems– comprising just the external walls, party walls and roofing – to complete, top-end-of-the-market products, which are supplied to site fully fitted. An example of this is from *Hufhaus*, made in Germany. With regard to SIRPs, we are not aware of many systems in current use in the UK

End-use market mix

We estimate that some 80 - 85% of demand for SIPS have been for housing, mainly split between private and social housing and a small proportion supplied to the self-build sector. Non-residential applications have included chalets on leisure parks.

SIRPs have mostly been used on a variety of residential applications including barn conversions, bungalows, private houses, social housing and apartments. Commercial applications include swimming pools and offices.

Market potential for reducing site waste

The SIPS industry is in direct competition not just with traditional housebuilding but also with the timber frame and steel frame housing manufacturers. As mentioned previously, the main barrier to increasing uptake is the relative cost of building and installing a SIPS building compared to a timber frame system. The other main barrier is that supply capacity is much lower than timber frame.

Over the last year or two there had been a renewed interest in SIPS with regard to social housing developments. Historically in the UK the use of SIPS has mainly been confined to small, bespoke housing developments consisting of just a few units, and the self-build market. In recent months there have been larger developments using SIPS.

In terms of end-user applications, over the medium term, the main driver will be the growth in demand for fast track social housing construction. This is likely to be underpinned by a dozen or so of some of the more innovative and progressive RSLs'.

Apart from speed of construction, the key advantages for clients in using SIPS are that:

- They typically have a very low U-value at around 0.15, and as such provide better insulation than is available on most brick and block and open panel timber frame construction.
- As they do not require trusses and rafters, there is roof space that is not available with traditional and most timber frame methods of construction.

Although suppliers have not generally been marketing their SIPS as solutions to reducing site waste, where substituted for traditional construction they can contribute towards waste reduction in the following areas:

- They do not require blockwork, either for the foundations nor for the inner leaf and therefore there is no waste in the form of offcuts, discarded or damaged blocks and there is no need for pallets and shrinkwrap used for their transportation and on-site storage.
- No insulation needs to be installed on site and therefore there are neither offcuts nor packaging in the form of pallets and plastic wrapping.

Further back up the supply chain, the manufacturers have generally improved their production efficiency particular with regards to 'closing the loop' and so reducing process waste levels.

With regard to the OSB panel boards, some 7 –10% is typically generated as offcuts waste through operations such as rebating. Increasingly, manufacturers are now reworking offcuts from the main panels to use as spline joints. One respondent to our survey reported that in 2006 it his company is on target to reduce panel waste from 8% to 2-3%. A couple of years ago, those 8% of offcuts waste were sent to landfill.

The other area of waste is that of insulation offcuts. These cannot be fed back into the loop and therefore the only options are to find external recycling options or to dispose of as mixed waste and sent to landfill. However, unless volumes are sufficient there is no demand for this.

Most manufacturers use polyurethane (PUR) for insulation and the approaches to reducing and recycling waste vary from one manufacturer to another. One manufacturer has succeeded in minimising PUR waste through changing production methods. Formerly, PUR would be injected between the panels until it was flush with all the panel edges. When it had set, a volume of material 100mm deep x 50mm width all the way around the panels would have to be routed out to form the joins. This material was subsequently binned and sent to landfill. Now, the PUR is injected between the panels leaving 100m depth x 50mm width space towards the edges of the panels and so routing is not longer required. This has resulted in almost a total elimination of PUR waste.

Several other manufacturers are currently investigating ways of recycling PUR waste. One is currently trialling with grinding routed PUR waste, bagging it up for supply to third parties as floor insulation in existing homes. Another is trailing with powderising PUR waste to be bagged up and supplied as loft insulation on existing buildings. It is also looking for markets for chipped OSB waste.

As with volumetric modular systems, most SIPS buildings have been procured under supply and fix contracts on relatively small schemes. To date, there have been no developments sufficiently large enough to warrant 3rd party interest, until recently. Therefore, there are no independently produced case studies to demonstrate the extent to which SIPS construction can limit site waste, when substituted for traditional building methods.

Suppliers are typically offering systems with lifespans of up to 60 years. Although ease of disassembly for recycling has not generally been built into designs, the various components can be dismantled easily. The OSB panels are recyclable as is expanded polystyrene, as used on some products.

3.4.5 Pre-cast structural panels & panellised building systems

Market size and trends

It first needs emphasising that in general, the suppliers of pre-cast panellised building systems do not consider themselves to be in direct competition with each other, but with suppliers of other types of offsite building systems and traditional construction.

There are some estimates that indicate the market for pre-cast panel products to be worth £80 - 90m, at manufacturers sales prices, although it appears to us that this may include pre-cast cladding, which we define separately. This is because pre-cast cladding is used for facades while, in the context of this report, pre-cast panels are used as key structural elements for the external walls and often for party walls. However, confusion can arise as pre-cast cladding is supplied as both load-bearing and non-load-bearing. In the main, though, pre-cast cladding is mostly used on bespoke architectural applications, while pre-cast panellised products are mostly used for houses, industrial buildings, student accommodation and budget hotels.

A key area of demand is for pre-cast basement systems, which are essentially pre-cast insulated panel assemblies. The key drivers here are the current shortage of suitable land available for development and the demand for additional room space.

Products and End Use Applications

The types of pre-cast panellised systems vary from one supplier to another, although the most basic product type consists simply of pre-cast floors and wall panels which are pre-formed for window installation. Higher-value products are typically supplied with insulation, plastering on the internal faces and occasionally external wall finishes, whether cladding or render.

Market potential for reducing waste

Structural walls panels on their own, and pre-cast panellised building systems, are used as fast-track substitutes for brick and block, and blockwork & cladding/render building methods. The more basic options replace the need for inner-leaf blockwork, mortar and more often than not internal wall plastering.

Insulated panels negate the need for insulation to be fitted on-site and this eliminates insulation waste and the associated packaging waste.

Typically, manufacturing conditions are highly controlled, with panels, and other pre-cast products, being manufactured using moulds. Consequently, wet concrete waste levels are negligible to non-existent, although there is inevitable some insulation waste, where factory-fitted, but this is less than for site-installed insulation, mainly with regards to packaging.

As noted previously, some pre-cast panels systems simply comprise concrete panels. On site, wallpaper or emulsion is typically applied directly to the surface, which in turn affects the ease of post-use recycling. Similarly, there are some 'sandwich' panel systems where there are two concrete panels and a foam insulation core, which may prove difficult to recycle after disassembly/demolition.

As for standard panels without insulation, the only post-use application is crushing for use as a recycled concrete aggregate. Therefore, as a type of recycled aggregate is the only suitable application. Demolition rather than careful disassembly is likely to be the main approach to handling end-of-life panels.

3.5 Bathroom & Kitchen pods

3.5.1 Definition

Within our definition, pods are discrete volumetric units that are factory fitted with building services equipment e.g. electrical circuitry, lighting and plumbing, sinks etc., but which do not form part of the building envelope. The majority of manufacturers supply bathroom and kitchen pods. These are typically available in frames made either from concrete, steel or GRP. Concrete pods are typically load-bearing structures that are often installed into a building's structural concrete framework.

GRP and steel pods are either similarly installed on site through being lowered by crane into a steel structural framework or they are supplied direct to modular building manufacturers to be fitted inside larger volumetric modules. As such, it is difficult to make a clear distinction between pods and volumetric modules, as defined in Section 3.3 and, as such, there can be an element of double counting when trying to estimate the size of the overall MMC market. Some manufacturers may define discrete bedroom units as pods, but we have included them in the volumetric modules sector as they generally form part of a buildings envelope.

3.5.2 Market size & trends

The UK market size for bathroom and kitchen pods is estimated at around 35,000 units in 2005, worth some £125m at manufacturers sales prices.

Currently the market for pods in the UK is positive and showing growth, the key drivers for this are mostly derived from the key end-use sectors:

- University new build accommodation is growing and there is claimed to be a shortage of beds for 100,000 first year students and many 2nd and 3rd year students are in poor quality accommodation. This sector is expected to be buoyant for maybe 5-8 years into the future.
- MoD SLA build has been stimulated by the SLAM programme to build over 21,000 rooms over the period 2003-2012. Other Defence sector spending includes Prime Contracts and Project Reader, which is a package of improvements to SLA in Land Command locations across the UK and Germany. This suggests a further 24,000 bedrooms to be built over the next 5-10 years, making a total of over 45,000.
- Health accommodation and hotel accommodation numbers are expected to remain reasonably static over the next few years, though there is a shift in the hotel sector to more upmarket applications.
- The residential sector is also expected to provide motivation to the market over the next few years, with an increase in affordable housing, flats and apartments. The numbers of flats and apartments has increased from approximately 29,000 units in 1999/2000, to an estimated 80,000 in 2004/2005. However, it is primarily in the affordable and social housing sector that the use of pods is expanding and is expected to provide a stimulus to the market over the next few years.

There now seems to be a widespread view that kitchen and bathroom/shower pods are now of a generally higher quality than traditionally built alternatives, particularly with regard to cellular – type accommodation. This attitude is now generally underpinning the increase in the specification for pods.

3.5.3 End-use market mix

Our estimates of the mix of pod usage in key sectors are shown below. Bathroom/shower pods are specified more frequently than kitchen pods (estimated at around 85-90% bathrooms), and so partly explain the high levels of use in student accommodation, MoD SLA and budget hotels.

Apartment blocks

The key applications for pods in the residential sector are apartment blocks, a significant growth area in recent years, mainly in more up-market premises. In top-end flats, generally the best quality fittings are installed, so ironically this seems to offer less flexibility to the buyer and more opportunities for pods.

Key market drivers behind the use of pods in apartment blocks market include:

- Demand for aesthetics and design, such that installation is seamless and owners are not aware that it is a pod.
- Durability and robustness of the pods for public sector use.
- Flexibility of design, such that individual requirements can be addressed.
- Speed of installation

Universities

Within the student accommodation market, the key demand drivers include:

- Speed of installation, as student holiday times are the main opportunities for building.
- Costs of pods into this sector are competitive at around £2,000/unit

- This sector's demand is likely to be sustained over the next 5-8 years, before accommodation supply begins to match demand.

Hotels

Bathroom pods are used in the budget sector and the mid to premium sectors. Where bathroom-only pods and bed/bath-combined pods are used, products are usually specified individually by the architect, client or interior designer, for the pod manufacturer to put together, although in some cases manufacturers may recommend products.

The use of pods in the hotel sector has in the past been criticised due to a number of compatibility problems, causing leakages. These problems have now been solved and the use of pods should start to increase again. Some manufacturers offer a design service but this is usually only on smaller contracts.

Important aspects of POD usage, which are relevant to the Hotel sector, include:

- Aesthetics and design are key issues.
- Flexibility of design, such that individual requirements can be addressed.
- Higher value products - from £3,000 - £10,000.
- Market is currently static, but is projected to pick up in the near term future.

3.5.4 Market potential for reducing waste

Growth forecasts are very difficult in this market as they are dependent upon large individual contracts. We anticipate that over the next 4 - 6 years, the hotel, university accommodation and MoD SLA sectors will show strong growth, while the domestic affordable housing sector is expected to grow reasonably strongly, with the emphasis likely to be on high-rise apartment blocks within cities and large towns.

Thereafter, the MoD and university sectors may well begin to slow down and the market will become more dependent upon the affordable housing sector, which we expect to continue growing at a modest rate, reflecting the shift to smaller households.

Because pods are a well-established form of MMC, architects and contractors are now comfortable with specifying pods over traditional construction methods for cellular accommodation.

The main barrier to market growth still lies with the reluctance among specifiers in the private housing sector to choose pods over traditional build. However, this may change due to the increasing level of use in social housing, which is proving that pods are a viable option, both in terms of quality and competitive cost. According to some of our respondents, one of the key areas that require reworking on traditional newbuild, due to factors such as miscalculation in or misreading of the design drawings, is that of fitted kitchens. This typically results in significant levels of waste and, sometimes, complete kitchen units have to be replaced.

Although fast-track requirements and product reliability have been the key drivers behind demand for pods, anecdotal evidence from several leading contractors indicates that the substitution of pods for traditional methods for constructing bathrooms/shower rooms, washrooms and kitchens has led to a reduction in several product waste streams notably:

- Pallets, cardboard packaging, shrinkwrap and banding used for sanitaryware, tiles, fittings, mirrors and taps, 'white goods' for the kitchen and fitted kitchen components
- Damaged ceramic ware, floor and wall tiles
- Damaged fitted kitchen units and incorrectly installed kitchen units that require reworking
- Less worktop offcuts
- Plastic bags for plumbing components and lighting components
- Paper bags for tile grouting mixes
- Tins and plastic pots for paint and adhesives
- Unused grouting and mastics

Overall it appears that where substituting pods for traditional methods of constructing bathrooms and kitchens reduces net waste levels bare typically reduced by 30-50%. The only waste generated from the installation of pods themselves is the shrinkwrap and the cardboard door units used as the packaging.

In accordance with European benchmarking standards, there are strict quality control processes and according to the manufacturers there is constant monitoring of waste control procedures. Most manufacturers have closed loop systems whereby offcuts material is reused on lower specification areas.

Although the main drivers behind demand for pods have been speed of installation, standardisation and uniform quality, a few manufacturers do use sustainability/waste reduction as a marketing tool. One managing director stated that it has the ISO9000 rating and does use this to sell its systems. Most manufacturers contacted, however, stated that this is not an issue when marketing their products.

In general, steel frame and concrete pods typically have lifespans of 25 - 40 years. The MoD, however, specifies 60 years. Although ease of disassembly is not necessarily built in product designs, it is generally easy to remove the fittings from the GRP casings and to detach the casings from the frames. While steel frames can be sent for re-processing and concrete crushed into a recycled concrete aggregate, there is obviously a greater difficulty in recycling the GRP elements.

3.6 Building Envelope Components

3.6.1 Definition

Included within this section are prefabricated components that form part of the building envelope i.e. the external façade and the roofing. As we have defined it, the three main product groups where we provide some level of detailed analysis include:

- Composite panels
- Pre-cast concrete cladding
- Light steel framing (LSF) systems

We have also identified two other product markets that are currently very small but could well grow to be significant sectors in their own right

- Panellised brick cladding systems
- Modular GRP canopy/porch roof systems

Composite panels – or insulated or 'sandwich' panels - typically comprise 2 sheets with a core material sandwiched between the sheet inner surfaces. The core material may consist of a polycarbonate stiffener, to permit bending round columns, architectural details, etc, without crinkling, or the core may comprise an insulating medium such as a plastics foam or mineral wool, to increase thermal efficiency and reduce heat loss. Composite panel leaves or skins are mostly manufactured from profiled steel and to a lesser extent aluminium. Other materials include calcium silicate and high pressure laminates, with a growing sector represented by pre-cast concrete and glass reinforced concrete materials. The visible external surface, for architectural purposes, may be specified as 'flat', but even 'flat' sheets will undergo forming operations to make the features for securing the two leaves and core. Profiled sheets are available for composite, twin skin and single skin products, while all metal sheets have a degree of profiling.

Pre-cast concrete cladding – this sector covers both load-bearing and non-load bearing panels made from pre-cast concrete and used for external wall cladding. Reconstituted stone and glass reinforced concrete (GRC) are also included within our market definition. Specifically excluded, however, are applied stone facings, veneers and brick slips.

Pre-cast concrete cladding products include single leaves with a bonded thermal insulation layer, built-up multiple skin systems and pre-cast composite panels in which foam insulation is inserted between two concrete leaves which are fastened with tie-rods. Twin skin built up systems may include light-block inner leaves and appropriate insulation elements. GRC cladding panels include single skin and composite systems, which may offer weight advantages of as much as 80% when compared to a corresponding concrete panel, although panel size and the possible need for suitable frames/bracings have to be carefully correlated, dependent upon the application and the required strength.

The assembly and erection of panels may include mounting onto a structural frame or fastening to structural elements of the building. These include an increasing element of pre-fabrication, with for example factory-fitted and glazed windows in concrete 'punched' panels, which can subsequently be craned off a lorry and into position in one operation.

Pre-cast concrete cladding panels can be supplied in a wide range of homogenous finishes, including grit blasted, etched and polished, with reconstituted stone including natural aggregates to reproduce the effects of natural stone such as Bath or Portland stone, for example. GRC can also be designed and produced with a reconstituted stone finish, to reproduce the effects of varieties of natural stone.

Light steel framing (LSF) systems are typically used for supporting facade systems – comprising insulation, drylining and external wall cladding. They have been in use for around 12 years, largely as an alternative to traditional brick and block construction for apartment blocks and non-residential buildings of usually up to 6 storeys. LSF systems have 2 basic applications:

- Infill panels - light framed steel stud structures fixed between the mainframe members, made from either steel or concrete (in-situ or prefabricated)
- Continuous panels – steel stud frames connected to the outside of the main structural frame

LSF systems are broadly split between 'stick' systems, which are site-assembled, and frame systems manufactured offsite. Frames are further split between open and closed types. Open frames can be either be load-bearing or non load-bearing and are essentially bare light gauge steel panels They are typically either supplied direct to volumetric modular building manufacturers or to site where they can be used as infill panels or for continuous façade construction.

Closed frames are the newer products on the market and there are a few suppliers offering proprietary systems that do vary slightly between manufacturers. These are factory-assembled frames that are supplied to site, already fitted with the drylining, insulation and sometimes the cladding components, according to client requirements.

LSF systems supplied to site are typically delivered in flatpack form. They are craned into position where they are attached to either heavy gauge load-bearing steel or concrete frames. The main advantages put forward for the use of LSF systems is that they do not require scaffolding and they are generally faster to erect than traditionally built external walling.

While 'stick' systems and closed frames systems are usually delivered to site, the main area of demand for open frame systems is the modular building sector. Consequently, in trying to establish an overall MMC market figure, there are issues about double counting.

Not included within our definition here are light steel, load-bearing panellised modular housing systems.

3.6.2 Composite panels - for exterior walls & roofing

Market size & trends

In 2005, the total metal cladding market – including both wall and roof cladding - is estimated at around 27m sq m. Of this, composite metal cladding accounts for around 35%, with standard twin skin systems – built up on-site and single skin products - accounting for most of the other 65%.

The metal composite roof and wall cladding sectors have sustained relatively good levels of growth since the late 1990's, to values of around £240m and £105m respectively in 2005. Composite panels have gained share at the expense of site-assembled twin-skin systems due to the following factors:

- The general trend towards prefabrication in the construction industry influenced by the Egan report and the increasing deficit of skilled labour, with composite panels able to offer advantages in terms of ease, speed and safety of installation.

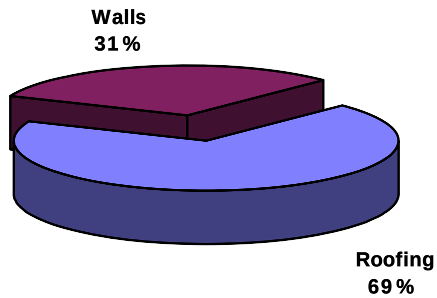
- Faster construction cycles compared to twin-skin, and surety in terms of completion dates.
- Reduction in panel breakages and installation times arising from innovative 'cherrypickers' aimed principally at the composite sector.
- Superior insulation properties in comparison to many twin-skin products, which can suffer from 'cold bridging' caused by metal-to-metal contact in attaching outer sheets to liners.
- Airtightness - composite panels offer a simpler and more assured method of achieving an airtight shell.

Whist the trend has been dampened to some extent in recent years by issues relating to fire issues, with twin skin offering the advantage of non combustible glass fibre insulants in preference to polysicyanurate foam which is flammable**,** there an increasing range of composite panels now available with LPCB approval.

Product mix

As indicated in Chart 17, the metal roofing sector is larger than the market for walls, mainly due to the large span installation found on warehousing and buildings located on industrial, retail and business parks. Steel accounts for some 95% of this sector with aluminium accounting for just 5%.

Chart 17: Metal Composite Cladding Product Mix by Area 2005



Source: AMA Research/trade estimates

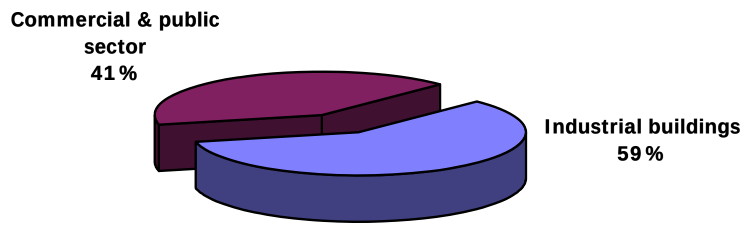
Due to factors such as requirements for aesthetic appearance there is a larger proportion of aluminium used for walls at around 10% although steel is still dominant with a 90% share.

Generally, there are two types of insulation used in the construction of the core, foam and mineral wool. Foam is virtually always used with roof panels and accounts for around 70% of wall panels.

End-use market mix

Industrial buildings account for around 60% of metal composite panel installations, while commercial usage accounts for the remaining 40%.

Chart 18: Metal Composite Cladding End User Mix by Area 2005



Source: AMA Research/trade estimates

Aluminium composite panels, being more expensive than steel panels, are mostly used on architectural applications.

Market potential for reducing site waste

Combined with the advantages outlined above, composite panels are expected to continue to show further growth over the next few years, mainly at the expense of site-assembled twin-skin systems and single sheet products. In theoretical terms, there is substantial room for growth, from the current market share of 35%.

Several years ago, composite products were considered relatively expensive compared to twin-skin products, mainly because of the need to incorporate breather membranes and vapour control barriers in composite products. However, increasing labour costs in the construction industry has considerably narrowed the gap in terms of installed prices, further encouraging the development of the composite sector.

Although Building Regulations insulation standards are the key driver behind increasing levels of specifications for metal composite cladding, there are also significant waste savings to be made through their substitution for systems built on site, including: -

With on-site constructed twin wall systems –also referred to as built-up systems – the insulation core is mostly made from glasswool or rockwool quilts, which are typically supplied in standard sizes. While there is some element of offcuts, it appears that a more common source of wastage is material that has been damaged because of poor on-site storage or handling.

With single metal panels, used either on single skin or twin-wall applications, damage does occur through careless handling.

Composite panels are generally more robust, although they can be subject to damage if handled improperly and their substitution for site built twin-wall panels can help reduce insulation waste.

Panels are typically attached to a building's mainframe and to each other and flashings using threaded fasteners. As such, the removal of panels from the mainframe should not be difficult.

However, the insulation core of some types of composite panel is made from rigid urethane, which bonds to the inner walls of the panels. Therefore, disassembly is unlikely to be easy. However, the advantages with urethane insulation are that it has among the lowest of thermal conductivity ratings of all insulants and modern products are now free of CFCs and HCFCs.

With other types of composite panel, the insulation is made of mineral wool, which is easy to separate from the rigid panels.

3.6.3 Pre-cast Concrete Cladding

Market size & trends

Typically, pre-cast cladding is delivered to market on a supply and fix basis, with the UK manufacturers typically supplying their systems on a bespoke turnkey basis. Consequently, company turnover figures will include a significant element of added value from delivery, installation and post-installation services. This, and the fact that the market is driven by large bespoke contracts, makes it difficult to provide an accurate market size figure. However, accounting for this we estimate that at manufacturers sales prices the market is within the range £70 - 80m.

The lifespan of pre-cast concrete cladding is long, with products expected to have a life of around 60 years in comparison to 25-30 years for most other cladding products. The pre-cast sector is, therefore, more dependent upon new build applications than many other sectors, with key application areas including retail developments, high rise apartments, hospitals, commercial offices, hotels, schools, universities and architecturally designed buildings in general.

In recent years, the pre-cast sector has shown growth ahead of that of the overall wall cladding market, benefiting from increasing levels of PFI activity, particularly in health and education, a positive level of construction in the retail sector, particularly of high street shopping malls and significant growth of apartments driven by housing shortages in London and the South-East.

However, the market has been negatively affected in recent years by the downturn in construction of commercial offices between 2001 and 2003, influenced by high levels of vacant office space in London and the South East. This has been exacerbated by the architectural trend towards incorporating increasingly large areas of façade glazing.

Overall, underlying demand continues to be underpinned by the general trends towards MMC, and increasingly pre-cast panels increasingly being specified with windows and external insulation factory-installed, enabling manufacturers to add value. Other factors driving demand include the wide range of colours, textures and finishes that can be applied and the inherent fire resistant properties of concrete.

Market potential for reducing site waste

The outlook for the pre-cast concrete cladding market is generally positive over the next few years, reflecting demand from PFI projects in the health and education sectors and high-rise apartment developments. An upturn in levels of commercial office construction is also expected over the next few years as the level of vacant office space in London and the South East reduces. This is expected to benefit the pre-cast concrete sector, although growth will be moderated by the current architectural trend towards increasingly large areas of façade glazing, particularly in more prestigious developments. In the longer term, however, increasing legislation relating to energy efficiency, combined with problems of solar gain in the face of global warming, may reverse this trend back in favour of cladding products.

The main reasons for architects for specifying pre-cast cladding over in-situ cladding are that:

- In-situ cladding typically requires a large area on which to store the materials, lay down the formwork and mix the concrete and fit the insulation. Pre-cast panels are therefore preferable where site space is limited.
- They also are typically specified where there are tight construction deadlines. Time is saved through having to erect scaffolding and in preparing equipment for making the cladding on site.

Although, manufacturers do not generally cite waste reduction as a key marketing tool, there are areas where the substitution of factory-made cladding for site-assembled cladding does save on waste. The main ones are that there is no need for plywood formwork, scaffolding or for 'wet' trades, all of which typically generate significant levels of waste where in-situ methods are used.

As previously noted, pre-cast panels typically weigh 10 - 13 tonnes and therefore at the end of a building's life, removing these would be a major challenge. Following the demolition of a building, together with other types of rubble, concrete panels could possibly be crushed on site and recovered for used as recycled concrete aggregate.

3.6.4 Light steel framing (LSF) systems

Market size & trends

Our estimates for the size of the LSF systems market, by both volume and value, are primarily based upon data collated from previous interviews with key trade sources. For the purpose of this study we have decided to include site-built stick systems. Even though the cutting of light steel lengths to size generates offcuts, these can be recovered as scrap and returned to the steel processor for re-processing. Furthermore, stick-built frames are increasingly being substituted for brick & block constructed external walls in both the medium-high rise apartment block market and in the non-residential accommodation sector. As such, their use in place of brick & blockwork can reduce waste arisings significantly.

It is also important to stress that the total market size for LSF systems does not relate solely to the end-user sector, as a significant proportion of sales, particularly of open frames, are supplied into the modular building industry. Therefore, there is an element of double counting when taking the figures here together with those from volumetric construction. However, within the context of the overall MMC market size, this is negligible.

Taking these factors into consideration, we estimate that, by volume, the market for LSF systems is in excess of 1m sq m and between £50 –60m by value.

Key reasons for the current prevalence of stick assemblies over off-site light gauge steel frames are that:

- Specifiers generally prefer stick assemblies to frame systems where facades are not of uniform design or where there is a lack of, or limited, standardisation in design.

- Stick assemblies tend to be preferred for complex facades e.g. curved
- Clients can often be conservative and unwilling to allow the use of 'new' products that have not been tried and tested.
- There appears to be a widespread lack of experience or knowledge among many architects and main contractors regarding off-site light steel frames.
- Logistical or practical difficulties in manoeuvring crane on-site and/ or making deliveries, particularly on sites where space is constrained.

End-use market mix

Because the market is small, it is difficult to provide an end-user market mix. However, to date, the key areas of application for both 'stick' and offsite LSF systems are buildings of 3–6 storeys, mainly high-rise apartments, MoD establishments and university teaching buildings. Other sectors where they have been used include acute/district general hospitals, budget-mid market hotels, out-of-town retail, leisure/health and fitness centres, office blocks, industrial buildings and airport buildings.

Market potential for reducing site waste

As of 2006,the market for offsite LSF systems is fairly small but we consider the potential to be considerable. Underpinning the reasons for this are that:

- The use of offsite LSF systems save considerably on time and labour, compared to on-site construction methods. This factor is of particular importance to public and private sector fast-track construction projects where time is of the essence.
- LSF systems can be used on any type of building up to 6 storeys and therefore demand would not be jeopardised through being limited to a very limited number potential end-user markets.
- All products on the market now have BBA, BRE and or BS certification, which will serve as guarantees of quality to potential specifiers, who formerly would have been cautious about selecting untried and new technology.
- There are now a sufficient number of developments that have used different types of LSF systems to prove that they are viable alternatives to traditional cladding methods
- Bare open frame systems or systems fitted with insulation have been proven to be more cost-efficient than site-built alternatives on some applications.

The only barrier to the increased uptake is that the costs of buying completely fitted closed frame systems can be higher than site-built systems. However, many specifiers often do not build in opportunity costs into their costings e.g. downtime, delays, loss through waste etc.

LSF systems are typically supplied in varied states of completion ranging from bare 'stick' built systems that are site-assembled to bare panellised frames to frames with cement particleboard and insulation board attached to complete closed panel systems.

Where substituting open frame systems for traditional methods of façade construction – i.e. brick & blockwork or blockwork and in-situ cladding or render – the main material waste savings are typically:

- The elimination of block waste and associated packaging.
- The reduction or elimination of brick waste, unused render and cladding offcuts.

In addition to these waste saving, closed panel systems can contribute towards waste reduction typically arising from the delivery, site storage and installation of separate insulation, drylining and cladding or render elements.

We consider that this more than offsets any waste arising through the manufacturing process. Although the cutting of light gauge steel can generate waste levels of around 3%, manufacturers will usually recover offcuts for re-processing. While some contractors with site waste segregation policies will also recover scrap metal for reprocessing, other will dispose of scrap metal into mixed waste skips.

As with steel framed volumetric and panellised modular building systems, the disassembly of LSF components from buildings at the end of their life ought not to be difficult. This is because frames are typically constructed using the stud and track method of connection, whereby cold rolled galvanised 'C' steel profiled sections are joined together using self-drill/tap fasteners, bolts and rivets. With the façade and roof covering elements, the façade panels, insulation boards and drylining are all connected using a system of brackets, rails and self-drill/tap fasteners.

The steel components are all highly recyclable and are metal facade materials such as aluminium, and zinc and also brick slips, timber and slates. However, whether facing materials such as high-pressure laminates, GRP and terracotta will be recyclable in another 50-60 years time is open to question

3.7 MMC Structural Pre-cast Concrete Building Components

3.7.1 Definition

In categorising products there are inevitably overlaps between sectors. This is particularly the case with pre-cast MMC products, which span the widest product range of any materials. In previous sections, we have covered pre-cast pods, pre-cast cladding and pre-cast cross-wall panels used for construction. This section includes structural pre-cast components that are not used in the construction of the building envelope. Within the context of this report, these include both standard products and also proprietary systems that are relatively unique within the market: -

- Hollow-core flooring – typically used on ground floor applications as an alternative to ready mix concrete and formwork and timber flooring. This comprises slabs made from pre-cast pre-stressed concrete elements with continuous voids provided to reduce self-weight and achieve structural efficiency
- Solid flooring - these include ground beam and block systems used for ground floors.
- Basement systems – these are prefabricated systems designed to offer homeowners ease of conversion to additional room space.
- Columns – these are alternatives to in-situ systems that make use of ready-mix concrete and vertical shuttering.
- Pods – these can be load-bearing but they are mostly used in conjunction with structural frameworks and are included in a separate section. Most suppliers are specialists with the exception of CV Buchan.
- Staircases – used as standard for high-rise residential, schools, office blocks, multi-storey car parks etc.
- Balconies – mainly used for apartment blocks.
- Terrace units – mostly used as standard for sports stadia.
- Pre-cast dock leveller pits – this is a new system with only Roger Bullivant currently supplying.
- Pre-cast concrete inner wall panel.

There are also panellised systems for external and party walls, but these have been included in Section 3.4 - Panellised Modular Building Systems. Of those listed above, those systems that we consider offer good potential for helping reduce site waste levels are: hollow-core flooring, beam & block flooring, columns and pre-cast inner wall panels. This is not to say that the use of other types of pre-cast products cannot also make a contribution.

There are also three relatively new but significant concrete-based MMC that need to be considered as viable alternatives to traditional building methods as they have been demonstrated to contribute towards reducing site waste when substituted for traditional methods of construction.

- Tunnel form construction
- Insulating concrete formwork
- Thin joint masonry

Tunnel form construction is a new form of MMC in the UK and is specifically used for the construction of large-scale cellular buildings. Key end-use applications include student accommodation, standardised apartment blocks and terraced housing, prisons, hotels and barracks. It is essentially a formwork system that allows contractors to mould on-site the external wall, floor slabs and party wall elements simultaneously. They are particularly well suited to high-rise buildings of up to 40+ storeys and are commonly used in conjunction with other types of prefabricated elements such as pods and pre-cast cladding.

A definition of tunnel form systems is provided by the Concrete Society is as follows: '*With tunnel form systems, storey-height inverted L-shaped units are locked together to make inverted U-shaped wall, floor and ceiling forms, which are cast as a single unit. Doorways and corridors are boxed out, conduits are installed for lighting etc, and reinforcement fixed. The concrete is then cast. Heaters are generally installed inside the forms and the ends of the tunnels sealed. The raised temperature accelerates the strength gain of the concrete and the forms can be stripped and repositioned the next day. The forms are steel-faced; the resulting cast surfaces can be decorated with a minimum of preparation. Although the system is best suited to a regular arrangement of identical rooms, variations in width and height can be accommodated by the use of infill panels*.

The formwork itself is typically hired out to contractors and can be adapted on a project-by-project basis. As such, this can contribute towards overall project cost reductions, transportation costs and site storage. Key reasons for its growing popularity are:

- Speed of construction
- The elimination of the need for scaffolding, which both saves time and enhances site safety, as installation is undertaken using a mobile platform system.
- High thermal mass, which meets the ever-tighter Building Regulations requirements for improved thermal efficiency in buildings.

Insulating concrete formwork (ICF) has been developed as an alternative to the traditional method of setting ready mix concrete or concrete slabs and mortar inside a plywood frame. In the UK, ICF systems are mostly formed from expanded polystyrene blocks separated by plastic or carbon-fibre spacers that lock together. They serve to create a cavity or mould for the structural walls of a building. Ready mix concrete is pumped into the cavity to form the structural element of the walls. Usually, reinforcing steel bars are added before concrete placement to give the resulting walls flexural strength, as in bridges and high-rise buildings made of concrete

Thin Joint Masonry is defined by key supplier H + H Celcon as *"accurately-dimensioned aircrete blocks with… specially developed Thin-Joint mortar……..Thin-Joint blockwork enables walls to be built very quickly without having to wait the conventional 24 hours for the mortar to set before further loading can be applied".*

3.7.2 Market size & trends

Of all the sectors under review, the pre-cast structural MMC market is the most difficult to assess due to definition, i.e. what products should be included and excluded. Within our definition, we estimate that, in 2005, the market was worth some £90 -110m at manufacturers sales prices. This also includes insulating concrete formwork, but not tunnel form construction.

Structural pre-cast concrete is widely recognised for its soundproofing, acoustic, progressive collapse and fire resistant capabilities, which are driving long-term market penetration in the hotels, accommodation and 'party wall' sectors generally. This is a well-established sector with high-rise capability that continues to demonstrate significant growth. We anticipate that the market should grow over the longer term underpinned by:

- Demand for materials and products that provide insulation and fire resistance requirements as specified in the Building Regulations.

- The development of new MMC products combined with growth in demand underpinned by fast-track requirements, labour shortage and the need for improved site efficiencies including reducing waste levels.

Hollow-core flooring

Building Regulations requirements for improved soundproofing are generating increased demand for hollow-core flooring on upper floors and higher in preference to timber on housing and concrete slabs on multi-storey buildings. The other advantages in using hollow-core slabs are that they require no packaging and being lightweight, higher volumes can be transported compared to solid concrete flooring systems.

Beam and block flooring

This is typically used for ground floor construction as an alternative to in-situ ready mix concrete used with formwork. Some systems, such as *Jetfloor*, from Hanson Building Products, are used in preference to solid concrete floors on clay soil. In rapidly changing wet and drought conditions, clay expands and contracts which can result in putting stress on solid concrete, leading to cracks and weakening. With suspended floors this problem is avoided.

Insulating concrete formwork

One of the newest areas of development is that of insulating concrete formwork (ICF). ICF tends to be used for projects ranging from a small extension to a block of flats, generally up to around 3 storeys unreinforced. Currently, ICF is being tried out in various end use sectors including affordable housing with RSLs, where 3-4 storey apartments have been erected. Self-build has also been a traditional market for ICF, and continues to represent a significant sector in overall terms and is forecast to complement the applications previously mentioned.

Tunnel form construction

Tunnel form construction (TFC) is one of the newer forms of MMC to the UK, although it is well established in many West European countries.

TFC has been widely used on the Continent. In the Netherlands, it is a common method of building terrace house developments, but in the UK its use in the housebuilding sector has been fairly limited. The first scheme to use it was a £20m social housing development on the Nightingale Estate in Hackney Downs, on behalf of Samuel Lewis Trust (part of the Southern Housing Group). To date, other key projects where this method has been used have been a student accommodation scheme at the Queen Mary and Westfield College in North London and two hotels developments; the Radission Edwardian Hotel in Manchester and the Chelsea Village hotel in Central London.

3.7.3 Market potential for reducing waste

It is important to note that, in general, the manufacturers of pre-cast concrete MMC products are not so much in competition with suppliers of on-site concrete construction products, as with alternative construction methods e.g. brick and blockwork, steel and timber frame.

While the substitution of pre-cast MMC, TFC and ICF for on-site building methods has been proven to save on time, labour, transportation and waste, concrete products manufacture is still widely perceived as being highly energy intensive. It is fair to say the concrete construction products lobby has been defending its position very robustly and has been one of the most active sectors of the building products industry in the development of the MMC market.

However, we consider that the use of pre-cast MMC products and other forms of concrete based MMC will increase due to the advantages they offer with regards to high thermal mass, fire resistance, high levels of sound insulation, and low levels of labour needed for installation

In general, the substitution of pre-cast MMC products, TFC and ICF for traditional building products – e.g. solid flooring, columns and below ground blockwork – has eliminated the need for plywood formwork and shuttering. Although no data is available, it is clear that discarded formwork and shuttering accounts for a substantial element of wood waste, if not the highest proportion on non-housing developments. Through its substitution for traditional methods of constructing external walls, ICF also eliminates the need for the in-situ installation of insulation and associated packaging. Key pre-cast products such as hollow-core slabs also do not require packaging in delivery.

Typically, as the pre-cast manufacturing process uses moulds, there is very little material waste. Most, if not all, manufacturers recycle process waste such as sand, cement and aggregates. The recycling process typically separates out the solids and the cement slurry is kept in suspension and reintroduced to the production process.

The use of Thin Joint Masonry (TJM) has mostly replaced beam and blockwork at ground level on housing developments. A key benefit of TJM blocks is that they can be easily and accurately cut, sawn and worked on site. The precision cutting of blocks for use with thin layer mortar allows greater utilisation of the blocks, which can substantially reduce site wastage. On average, offcuts waste from the installation of standard aircete blocks is as high as 10%, but with TJM blocks, offcuts waste is generally less than 3% - a considerable saving in waste generation.

The other key area of waste reduction is the mortar. Thin layer mortar is a pre-mixed cement-based product that only requires adding to water to make an easily applied mortar. It differs from standard use mortar in that it sets far more quickly, so giving early stability to the construction. The depth of the mortar can be reduced from at least 10 mm to 3 mm or less. According to our respondents and two contractors that have used it, the substitution of TJM for traditional block construction reduces mortar usage by some 70%.

The main barrier to increasing the uptake of TJM is in finding enough people on site to train. There has reportedly been some reluctance among workers to using the new system, even though TJM has generally been well received at management level.

Upon disassembly or demolition, the main route for end-of life pre-cast MMC components is crushing for use as recycled concrete aggregate. However, some components, because they are composite – such as insulating concrete formwork – are more difficult to recycle.

4.0 End Use Applications for MMC

4.1 Introduction

The data and forecasts in that the following tables provides the basis of AMA Research's review of current markets for MMC and outlined below is a summary of our analysis of key potential areas of offsite construction within the major end use applications:

4.2 Construction Market Overview

The table below summarises contractors' output for new work by sector:

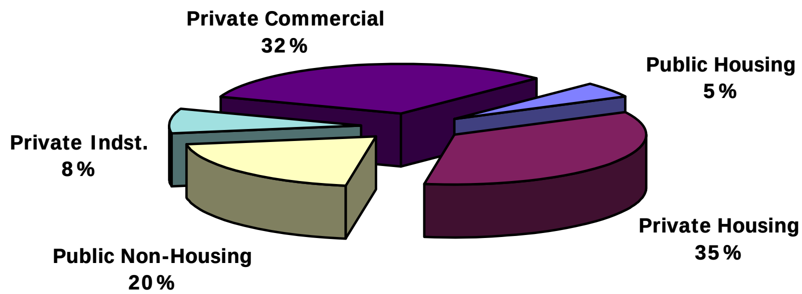
Table 19: Contractors Output – Public & Private Sectors 2004 / 2005 (£m – Current Prices)

Segment	New Work - 2004	New Work - 2005
Public Sector	13,100	12,900
Private Sector	37,700	39,400
TOTAL	50,800	52,300
Source: DTI/AMA Research		

As the table shows, new work output grew marginally in 2005, with a modest increase of around 4% in the private sector offset by a very small decline in public sector construction. Total new work is currently valued at around £52 billion (excluding infrastructure), with the MMC market typically valued at around £1.5 - 2 billion, depending on product definition, which suggests that MMC products typically account for around 4% of the construction market. However, this share figure slightly underestimates MMC's role as the valuation for MMC is at material level only and therefore a more realistic estimate would suggest perhaps around 6-7% in overall terms. Recent growth rates for MMC products have been outperforming the underlying growth in new orders, indicating wider acceptance in key sectors.

While we have not included a comprehensive review of construction output in this report, the chart below provides a brief overview of key sectors in 2005:

Chart 20: Construction New Work – Share by Key Sectors (2005)



Source: DTI

As chart 20 indicates, housing accounts for around 40% of new work, though the private sector is dominant with social housing only accounting for around 5%. Public sector non-housing accounts for around 20% and this is dominated by education and healthcare, though defence and Home Office expenditure are key sectors for MMC. Private commercial includes offices, hotels, retail etc., where MMC take-up is extremely variable.

As indicated throughout this report, the sectors offering the greatest potential for MMC in the medium term are:

- Education
- MoD
- Healthcare
- Housing
- Hotels
- Student Accommodation
- Retail
- Others – e.g.: Olympic Games

4.3 Education - schools & university buildings

4.3.1 Current use of MMC products

Schools & nurseries

To date, by far the most specified type of MMC used is volumetric and panellised modular construction, mostly for use as temporary classrooms and also for complete construction of nurseries and primary schools. Montessori, which operates a chain of nurseries, is a major user of modular construction. There have also been a large number of secondary school classroom extensions.

However, nearly all volumetric and panellised modular construction in the schools and nurseries sector has been under design & build contracts by the larger volumetric building manufacturers, in particular Terrapin and Rollalong. There have been very few developments where volumetric and panellised modular buildings have been delivered on a supply only basis

The use of other types of MMC products has been more limited, particularly on secondary schools schemes. LSF and pre-cast panel systems have been used on several secondary school developments.

Higher education

In the higher education sector, the main application for MMC products has been in the installation of volumetric modular bedrooms and bathroom pods. The use of volumetric modules in halls of residence has been quite high in recent years, with total student accommodation new build units currently estimated at around 15-20,000 bedroom units p.a. It is anticipated that this level will be sustained through to at least 2010. The use of volumetric modules on other applications in the higher education sector has largely been limited to teaching blocks and language laboratories.

There has been some use of LSF systems, the main areas of application being on faculty buildings e.g. newbuild teaching blocks.

4.3.2 Market potential for MMC products

The Building Schools for the Future (BSF) programme will be the largest construction programme in the UK and requirements for fast-track construction should favour the use of MMC. The main barrier is to increasing the uptake of MMC in this sector is likely to be the attitude among architects and specifiers, although this depends on which architectural practices and main contractors will be undertaking the work.

In the secondary schools sector, demand for modular construction and LSF systems, in particular, may be limited, as these types of MMC are best suited to facades that are regular and repetitive in design. However, there should be reasonable potential for washroom pods.

The primary school element of the BSF programme should lend itself to modular construction as buildings and classrooms are generally smaller than those in secondary schools. In addition, there is a high degree of 'repeatability' in terms of classroom requirements that lend themselves to a volumetric approach to construction, while minimising disturbance to existing operations will also be a key issue for specifiers in many projects.

The role of Government in influencing the specification process, coupled with the overall scale of the programme, make this sector a particularly attractive opportunity to increase MMC and achieve significant gains in waste reduction.

4.4 Defence

4.4.1 Current use of MMC products

The UK defence sector is currently a major area of demand for volumetric modules, LSF systems and pods. A key factor underpinning the use of MMC at many MoD sites is that garrisons are in operation 365 days a year. Therefore, where constructing key buildings, e.g. SLA units and dining facilities, there is a premium on the need to build as quickly as possible and to create minimum disruption. This means that it is often of paramount importance to minimise or eliminate excavation works and other 'heavyside' activities such as groundworks and piling. In addition, site security is a key issue and modular construction offers the opportunity to restrict the number of construction workers / subcontractors on sensitive sites.

Requirements for new buildings by the MoD include single living accommodation (SLA), administrative offices, training facilities, catering and dining facilities, washrooms, kitchens, etc., currently being delivered under three large contracts:

- Project SLAM – operated by Debut Services Ltd, a joint venture between Bovis Lend Lease and Babcock Plc.
- Project Allenby/Connaught – operated by Aspire Defence Ltd. The two lead partners are Carillion Plc and Kellogg Brown & Root. Mowlem Plc was the original partner to KBR before its acquisition by Carillion in February 2006.
- The Colchester Garrison PFI DBFO scheme – operated by RMPA Services Ltd
- Regional Prime Contracts (RPCs)– capital works

Under Project SLAM, Debut Services is overseeing the upgrading of the worst single living accommodation (SLA) to a 'grade 1' standard of physical condition by 2013. In total, around 21,000 bed spaces are to be upgraded by the end of the programme. In Part I - Years 1 to 5 (April 2003 – April 2008) - around 12,000 bedrooms will be built under 86 projects at 36 sites.

Each individual development is assessed separately against key criteria, such as geographical factors, area of sites, nature of access to sites, local labour availability etc, and, to date, a mix of construction methods have been used to construct SLA, which included volumetric modular, steel frame & pods and the use of LSF systems.

On the Colchester Garrison project, there has been an extensive use of volumetric modular buildings for SLA and other facilities. Of the 141 buildings, 23 have been built using volumetric modules.

Under Phase 1 of Project SLAM, volumetric modular construction has been used at several sites including:

- Royal Marines Poole – junior ranks SLA at Hamworthy - three 5-storey units comprising 226 junior ranks Z and 75 NCO rooms.
- Marne Barracks at Catterick – ten 3-storey buildings, comprising 330 modules, providing 560 bedrooms.
- Alexander Barracks, Pirbright – 123 Junior ranks Z rooms

There has also been extensive use of shower pods.

4.4.2 Market potential for MMC products

In general terms, the MoD is heavily committed towards MMC in all forms and will be a major user of MMC construction methods for accommodation over the next 8 years. Choice of construction method will be driven by time limitations, a high emphasis on site security, level of 'repeatability', site accessibility etc, and this is reflected in Project SLAM which will involve a mix of construction methods according to individual site requirements.

Project Allenby/Connaught is a PFI DBFO scheme with Aspire Defence acting as main contractor, covering a range of army garrisons in Aldershot and sites around Salisbury Plain. In total, these sites accommodate some 18,000 people. Overall, the contract is set to run for 35 years with an overall life value of £7bn. The capital element is worth some £1bn and involves the construction of 359 new buildings, 155 refurbished buildings and the demolition of 418 buildings. Of the 359 new buildings, 219 will be for SLA, including the provision of 10,700 Junior ranks Z rated bedrooms. In addition, 75 technical buildings and 47 dining facilities are planned.

Aspire Defence is delivering a programme of volumetric modular construction, the main focus being on 10,000 Junior ranks Z rated bedrooms. As for other buildings, there will be a mix of traditional construction – perhaps incorporating some MMC components and volumetric modular and steel/concrete frame & pod construction.

Under the Core Works programmes of the five RPCs, there is likely to be demand for modular buildings and concrete/steel frame & pods construction, not only on SLA applications but also on buildings such as offices, operations rooms etc.

Project MoDEL is a £180m plus stand-alone Functional Prime Contract, which was awarded in September 2006. The aim of the scheme is to consolidate Defence Estates London estate by relocating units and operations from 9 sites in and around the Greater London are to RAF Northolt, RA Woolwich and RAF Uxbridge.

These 3 sites will be expanded to accommodate relocated personnel and will include newbuild developments covering SLA, family accommodation, offices and operational facilities. However, no details about capital works requirements have yet been confirmed although it is highly likely that MMC will be a key element of the construction programme.

In overall terms, the MoD represents a major sector for MMC in the medium term, though current usage and awareness levels of the benefits of MMC are already relatively high and will, therefore, not require much further external input.

4.5 Healthcare

4.5.1 Current use of MMC products

Within the healthcare sector, the use of MMC products has mainly been limited to volumetric modules used as distinct units e.g. wards, A & E units and operating theatres at existing hospitals.

There has been some use of pods, although demand is relatively low at around 1,500 units p.a., which is the smallest of the principal markets for pods. The main applications appear to be nursing and care homes.

There has also been some limited use of LSF in the healthcare sector, mainly for use on general/acute hospital newbuild developments. PFI hospital developments offer significant opportunities for light gauge steel framing systems due to the large-scale bespoke designs of the major acute hospitals. To date, individual cladding installations have varied greatly in size, typically from around 3k sq m up to around 20k sq m. For example, large-span open frame systems were used on the major re-developments of the John Radcliffe Infirmary in Oxford, the Walsgrave hospital in Coventry and Blackpool Victoria Hospital.

Pre-cast cladding is also well suited to large hospital construction, as exemplified by the use of Trent's system by Carillion on the Great Western Hospital development in Swindon.

4.5.2 Market potential for MMC products

With the Government shifting the focus of public healthcare away from secondary to primary healthcare over the long term, there could well be increased opportunities for uptake of MMC as they should, in theory, lend themselves better to the fast-track construction typically required on primary care newbuild developments whether primary care centres or walk-in centres.

However, the use of MMC in NHS LIFT and ProCure 21 schemes has been limited, due a range of factors, not least a lack of experience or knowledge about the benefits of MMC, a lack of willingness or simply a negative perception.

In overall terms, as with education, healthcare represents a major opportunity in terms of current usage levels and the scale of construction programmes to achieve substantial growth in MMC and reduce site waste levels. Procurement processes such as LIFT and ProCure 21 have resulted in the emergence of key consortia, which can provide a relatively focused range of contractors and specifiers to be targeted to achieve change in approaches to the use of MMC.

4.6 Housing

4.6.1 Current use of MMC products

In general terms, the overall level of use of MMC in the housebuilding sector is low, although there are some notable exceptions and volumes are rising. Pre-cast concrete, timber frame and structural steel frame are the most specified types of MMC products.

In terms of mainframe structure, we estimate that MMC accounted for almost 19% of new housing starts in the private and social sectors in 2005, up from 17% in 2003. This is equivalent to around 40,000 units and timber frame construction accounts for the majority of this increase.

Social housing

With regard to other types of MMC product and other forms of MMC, the social housing sector is the most pioneering in terms of the range of MMC technologies used. The use of MMC is largely being driven by the Housing Corporation / English Partnerships and the more progressive RSLs. To date, there have been a relatively large number of social housing developments that have used a variety of MMC – all underpinned by Government directives for a minimum of 25% MMC content.

In addition to the 7,000 or so timber frame and the 2,000 or so steel/concrete frame dwellings built in 2005, other types of MMC products that have been used in social housing sector include volumetric and panellised modular building and components such as LSF systems, floor and roof cassettes, pre-cast foundations and SIPS. Since 2003, there has also been some use of tunnel form construction. Although we are not certain of the extent to which these have been used, the following examples illustrate some of the largest MMC developments in the sector.

- SIPS – although SIPS have been used on small developments, The Way development in East Manchester is by far the largest SIPS-based development in the UK to date, covering some 550 dwellings.
- Tunnel form construction – to date there has just been the one housing development using TCF - the Millennium Plus social housing scheme in Hackney Downs.
- Volumetric construction – the use of volumetric construction in the social housing sector has been greater than in the private sector, mainly due to progressive RSLS that have a positive attitude towards modular construction.

Private sector housing

To date, the main type of MMC system used in the private housebuilding sector has been timber frame construction, with an estimated 27,000 units erected in 2005. There were also around 4,000 units built using either steel frame or concrete frame. The use of other types of MMC has been more limited. SIPS have mostly been used on self-build schemes and a few small developments, but the level of use is small compared to use in the social housing market.

The use of volumetric and panellised modular construction has also mainly been limited to bespoke developments. The two most notable examples of (relatively) large-scale developments using modular methods are as follows:

- Panellised concrete structures – one of the largest housing schemes built from pre-cast panels is a development in Cambridge built for Martin Grant Homes. This consists of 35 properties each with insulated basement system, permanent formwork floors, pre-cast sunken patio walls, pre-cast internal walls and pre-cast stairs.
- Volumetric – the most notable private residential scheme using volumetric construction has been the MoHo project in Manchester, developed by Urban Splash. This was for a 102-room, 6-storey apartment block - Yorkon provided the volumetric modules and Banro Projects supplied the LSF system for the secondary façade structure.

4.6.2 Market potential for MMC products

Forecasting future levels in housebuilding output is extremely difficult. Short of a major economic downturn, at worst output will be relatively flat, though over the medium term, the growth rates of the last couple of years should be maintained. The Barker Review indicates the need for an additional 70k – 120k homes p.a. If achieved, this will increase annual output to around 300k, although there are no firm indications of timescales. The most significant area of growth is scheduled for Southern England.

Major development is also planned for the North. Around 5 million homes across the UK (i.e. c 20% of housing stock) were built pre-1919, the majority of these being in Northern inner cities. Of these, some 400,000 dwellings in the North are scheduled for demolition between 2006-16 while the ODPM has earmarked a potential 660k new homes by 2024.

In the social housing sector, Shelter estimates that there is a current shortfall of around 55k affordable homes each year and that to match this requirement and to cover a backlog of 22khomes, around 67k new homes will need to be built each year until 2015. However, over the short-medium term, there are likely to be major barriers to achieving significant increase in volumes; including planning processes, land availability, site skills shortages, prices/affordability, housebuilders attitudes (land banks, margins, shareholder interests, risk etc) and opposition to development on the Greenbelt.

Demand for affordable accommodation in London and other areas of high-density population – for key workers and first time buyers – underpins public sector housing schemes such as Key Worker Living, Sustainable Communities and the National Affordable Housing Programme. Because of the need for fast turnaround to meet the shortfall in housing stock in key urban areas, demand for MMC within the public sector has grown accordingly. It has been Registered Social Landlords' that have been pioneering the use of MMC, and this has subsequently had an influence on specifiers in the private housebuilding sector.

Forecasting housing volumes and the mix between houses and flats is difficult but a significant proportion of newbuild will be in existing urban areas. As a result, this factor, combined with the shortage of affordable and available land, means the focus on future developments will be most likely to be on 4+ storey apartment blocks. We, therefore, anticipate that there will a continuation of the rapid trend towards apartments seen over the last few years, as illustrated below:

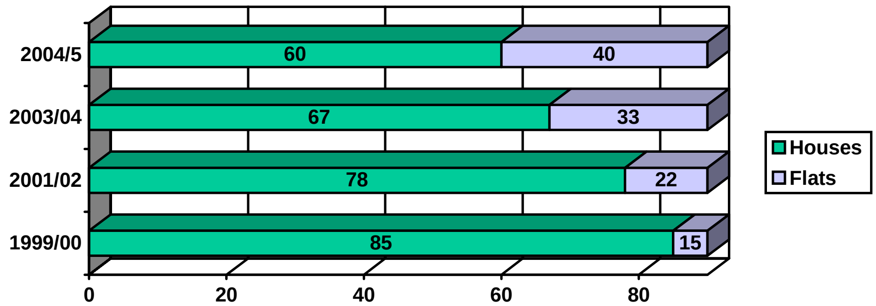
The overall figure for apartments in 2005/06 is now approaching 45%, with London and the South East well over 60%. The lack of available development land, coupled with sustained and rising demand for housing, will inevitably result in higher density housing which will largely be met with apartment building – which should provide good opportunities for MMC development.

As brick and block construction is unsuitable for blocks of 4+ storeys, the majority of apartment construction will most likely be either steel or concrete framework, and to a lesser extent timber frame. The use of steel and concrete framework in turn favours the use of prefabricated components such as kitchen and bathroom pods, floor and roof cassettes and LSF framing systems (open and closed) and also complete volumetric units. We also anticipate in the wake of the recent Millennium Plus development on the Nightingale estate in Hackney Downs, there is likely to be an increase in demand for tunnel form construction, not just for apartment blocks but also terraced housing.

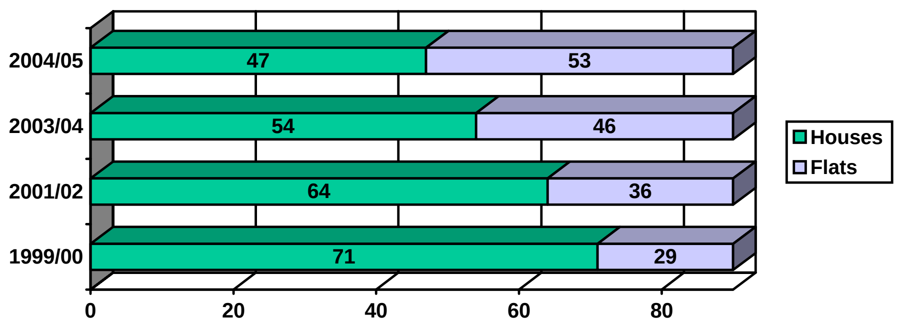
In the social housing newbuild sector demand for SIPS may also grow, although it will be mostly limited to 2-storey residences. The recent completion of the 550-dwelling development at The Way in Beswick, East Manchester, ought to encourage further large-scale SIPS-based developments.

Chart 21: Housebuilding Completions by Type of Dwelling:

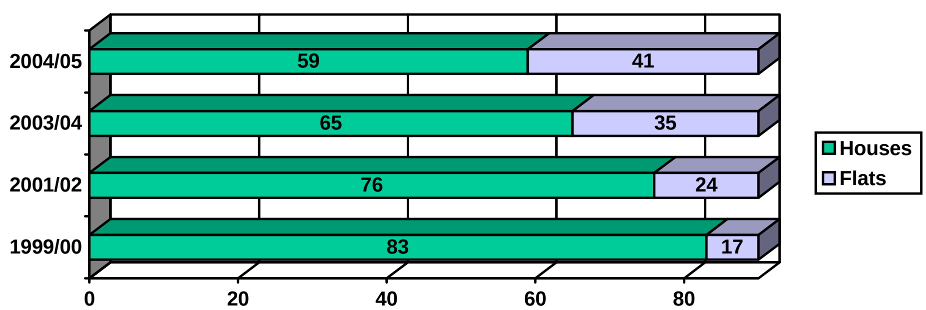
Private



Social



Total



4.7 Hotels

4.7.1 Current use of MMC products

Within the private sector, the hotel industry is by far the biggest user of MMC, pioneering the use of techniques such as tunnel form construction. It is also a key market for bathroom/shower pods, volumetric and panellised modular buildings, mostly in pre-cast concrete. Other pre-cast concrete components are also used extensively.

The key reasons for the high level of use of MMC in the hotel industry is that they enable fast construction turnaround time, which are paramount in order to be up and running as quickly as possible to start generating revenues.

It has tended only to be the three largest budget hotel operators that have the necessary economies of scale for modular construction to be a cost-effective solution. Other than these, most branded chain operators are not rolling out hotels in sufficient numbers on a regular basis either to be attractive to volumetric module manufacturers or to be cost-efficient for the operators themselves. Whitbread (*Premier Travel Inn),* Permira (*Travelodge*) and Intercontinental (*Holiday Inn*) have all specified modular construction on some of their developments, where suitable. In the mid-premium sector, demand has largely been for bespoke extensions

Bathroom Pods are used in the budget sector and the mid to premium sectors. Where bathroom-only Pods and bed/bath-combined pods are used, products are usually specified individually by the architect, client or interior designer, for the pod manufacturer to put together, although in some cases manufacturers may recommend products.

The use of pods in the hotel sector has in the past been criticised due to a number of compatibility problems, causing leakages. These problems have now been solved and the use of pods should start to increase again. Some pod manufacturers offer a design service but this is usually only on smaller contracts.

Panellised systems and LSF systems are used to quite a large degree on both budget hotel and 3-4 star hotel developments. Pre-cast concrete panel systems are used more extensively than either timber frame or steel frame.

4.7.2 Market potential for MMC products

The potential for increased demand for volumetric modules and pods within the budget hotel sector is almost entirely dependent on the roll-out programmes by the largest budget hotel operators namely Premier Inn, Travel Lodge, CHE Europe and Express by Holiday Inn. Over the medium term, potential demand appears to be reasonable, with an anticipated net increase of around 25k – 30k rooms over the next five years.

Several hotel groups operating within the 3 - 4 star sector have indicated development schemes over the next 5 years, where potential for use of modular construction appears to be significant. However, modular build would not seem to be well suited to most hotels at the upper end of the 4 star and 5 star sectors, where factors such as complex design, country or historical image tend not to favour their use.

4.8 Student Accommodation

4.8.1 Current use of MMC products

On newbuild or major refurbishment schemes, university estates departments or private sector developers appear to be increasingly inclined towards specifying or allowing the use of MMC due to 2 main factors:

- Build time is typically limited to the student holidays and therefore speed of construction is of the essence, particularly during the summer vacation ahead of the new intake of 1st year undergraduates
- Student communal accommodation is typically uniform in design and capable of housing large numbers of students and so is well suited to MMC.

To date, the main types of MMC that have been used are steel/concrete frameworks & pods, concrete panellised modular systems and volumetric construction. Traditional build is now not generally used to build student accommodation unless factors such as planning restrictions, layout and ease of site access make it preferable to MMC. This appears to be the case in congested, high-density areas such as Central London. Here, the main barrier to using MMC systems is restricted access to trailers carrying modules and height restrictions for cranage.

There is no available data on the volume of volumetric modules used in this sector, but anecdotal evidence suggests that uptake has been relatively low compared to pod based systems, but is growing strongly. In the student accommodation market, the main application for pods is for shower units. It is estimated that around 6,500 shower pods were installed into either concrete or steel frameworks in 2004.

We are not certain to the extent to which concrete panellised systems have been used in the student accommodation sector, but the largest application to date has been the installation of Bell & Webster's *Fast Rooms* System on a 1,600-bed development on the University of Hertfordshire's De Havilland campus in Welwyn Garden City.

4.8.2 Market potential for MMC products

The Higher Education Funding Council for England (HEFCE) forecasts that number of students in university accommodation is set to rise from around 290,000 in 2004 to 293,000 by 2007 – a relatively flat period following changes to student financing. It is expected that this figure will increase thereafter as universities try to meet the government's aim to send half of all school leavers into higher education by 2010.

There is an estimated shortage of beds for 100,000 1st year students and many 2nd and 3rd year students are in poor quality accommodation

It is estimated that to meet the current rate of growth in student numbers, around 15k – 20k new rooms will be needed each year to at least 2010 and possibly up to 2015.

The opportunities for MMC, therefore, are likely to be high for both volumetric modular, panellised and concrete/steel frame & pod construction.

4.9 Retail - shops, restaurants & pubs

4.9.1 Current use of MMC products

Overall, the uptake of MMC products in the retail and restaurant sector has largely been limited to volumetric modular buildings, composite panels and to a lesser extent washroom pods.

In the shops sector, the main driver behind demand for volumetric modules has been change of ownership and rebranding in the neighbourhood convenience store sector and growth in petrol station forecourt retailing.

In the neighbourhood store sector, most of the recent demand for volumetric modules has been from Tesco for its *Tesco Express* format. Most other operators have not been rolling out new stores in sufficient volume to justify the use of volumetric modular construction on economic grounds.

Although there has been a marked decline in the number of petrol stations, down by almost 50% between 1990 –2006 to less than 10,000 sites, forecourt retailing continues to grow, with sales up from under £3.7bn in 2003 to over £3.8bn in 2005. Underpinning this growth has been:

- increasing levels of competition from the supermarkets in fuel sales
- falling margins in fuel sales and the need to increase overall margins
- increased operating costs
- rationalisation forced by mergers of oil companies.

The other main are of use of MMC has been by McDonald's and Pizza Hut in the construction of stand-alone outlets in retail parks and leisure parks.

4.9.2 Market potential for MMC products

In the petrol station forecourt sector, Tesco is rolling out additional *Tesco Express* stores at forecourt sites to around mid 2007.

In the neighbourhood store sector, other than the anticipated new openings of *Tesco Express* and *Sainsbury Local* stores, which will mostly be volumetric in construction, most other operators have no plans for large rollouts of new stores. Their focus will mainly be on interior refurbishment and changing fascias, neither of which are likely to generate much demand for MMC products.

Elsewhere in the retail sector, the use of MMC, in particular volumetric construction, will mainly depend on McDonald's and Pizza Hut's future rollout plans. Both companies have publicly expressed their intentions to add around 40 –60 new sites a year to around 2010.

4.10 Other End Use Sectors

4.10.1 Introduction

This section brings together other smaller construction markets where there has been some use of MMC, albeit to a lesser extent than in the MoD, SLA and hotel sectors. These include:

- Prisons, young offenders institutions and detention centres
- Sport & leisure including the Olympic Games
- Offices

4.10.2 Current use of MMC products

Prisons & detention centres

At over 77,000 inmates and rising, England and Wales's prison population is at an all time high. A key problem for successive Governments has been how to cope with the increasing number of offenders now that existing capacity has been reached. Building more prisons is proving to be a controversial solution, not least because of newbuild cost and the costs of keeping offenders locked up.

A major challenge for the Prison Service is being able to respond quickly to changes in demand for prison accommodation. To meet short notice requirements, the most cost-effective solution used has been to specify brick clad steel-framed units at existing prisons. According to the National Audit Office, these types of units cost around £1,700 to construct each place p.a. over the lifetime of the building, taking an average of 183 days to build. The other main alternative, modular temporary 2-storey units have proved more expensive and prone to problems. These have tended to cost £5,600 each place p.a. over the lifetime of the building, and take around 134 days to build, compared to an expected 49 days in the original business case.

Between June 2002 and January 2004, the Prison Service constructed 29 modular temporary buildings in 21 existing prisons (providing 1,160 places) and 24 brick-clad steel frame units in 14 existing prisons (providing 920 additional places). The Prison Service also reclaimed a further 198 cells and converted a building in Norwich Prison to provide 40 additional places

To meet longer-term objectives, PFI has been used as the main procurement route for larger newbuild schemes over the last 10 years. Underpinning this had been the need to reduce construction times, previous to which most traditionally procured contracts had tended to overrun, in order to meet anticipated growth rates in the number of inmates.

According to the National Audit Office, since the introduction of PFI, average construction times have been cut by around 45%. Key to this has been the increased use of pre-fabrication, with the use of concrete panel systems and concrete modules being the most frequently specified. The leading supplier of concrete modules is Pre-cast Cellular Structures, a joint venture between Tarmac Ltd and Composite Ltd., which claims to have undertaken in excess of £100m worth of contracts since 1999, equivalent to 3,740 cells.

The use of steel-framed has mainly been used on smaller local prison schemes, where critical problems with overcrowding have underpinned the need for fast-track construction. Recent developments include:

- HMP Send - a design & build scheme with a capacity of 120. Rollalong was the prime contractor
- Castle Huntley & Corton Vale - a design & build contract between Waco UK and the Scottish Prison Service for 2 half-way houses to accommodate 200 bedrooms
- HMP Whatton - a design & build development by Caledonian Building Systems for 420 bedrooms.

In recent years, the rise in immigration levels combined with terrorism threats has underpinned Government plans for new detention centres. The UK detention estate has a capacity of over 2,660 spaces, the biggest sites being at Yarl's Wood and Harmondsworth. Both centres were built using modular construction methods.

Commercial Offices

The commercial office market, so far, has largely been resistant to MMC. Key to this is the perception among clients and specifiers that most systems are not suitable due a combination of factors, including: -

- Lack of major developments that successful prove the suitability of MMC to certain types of office newbuild, mostly the types of buildings situated on business parks
- The perceived lack of suitability of most types of MMC for bespoke major office schemes. This is combined with the fact that for many architects, high-value and prestigious office developments are often considered flagship projects that demonstrate their design skills, which they consider the use of MMC would undermine. The only exception is the use of bespoke pre-cast cladding, which is considered a high-specification product.

To date, the only significant application for MMC in the commercial office market has been the use of profiled composite cladding on major business park office developments.

Public toilets/washrooms

Washroom pods are the most commonly specified type of MMC product, used at airport termini, motorways services stations and railway stations. This sector is largely restricted to WCs and basins, with the exception of a small number of shower enclosures installed in some airport terminals and as a result is relatively low value.

4.10.3 Market potential for MMC products

Sport & leisure

Over the next 5 years, perhaps the biggest single potential market for MMC will be the Olympic Games construction programme. Because of the specialist bespoke nature of this massive building programme, this is covered in Section 4.11.

Commercial offices

The permanent office-building sector has not yet proved to be a significant market for MMC. This has been due to issues such as client preference, lack of suitability, either due to building height or restricted site access, and the bespoke nature of much office design. There has been some limited use of volumetric modules as back-offices on out-of-town retail outlets such as B & Q superstores.

The use of MMC that require cranage – e.g. LSF systems, pre-cast structural panels and pre-cast cladding - are not generally considered well suited to developments in areas with restricted access, e.g. city and town centres. But, they would appear to be more appropriate for newbuild developments in business parks and other areas with unrestricted access. However, current uptake levels are very low.

4.11 London 2012 Olympic Games

4.11.1 Overview

On July 6th 2005, the International Olympic Committee announced that London would host the Olympic Games in 2012. The decision followed intensive planning and fast paced decision-making on behalf of the LDA and 4 local authorities responsible for the site of the main Olympic Park. During Q4 October 2004, plans submitted by EDAW Plc on behalf of the LDA were approved and included in the London 2012 bid document.

The bid document included a comprehensive outline of proposed venues to be used for different sporting events, which included a mix of existing venues, new sites and major refurbishment projects.

Whilst some construction activity has already begun, activity will rise each year until 2009 when a total of 17 major Olympic specific projects will be ongoing. By 2011, most of the major construction activity is scheduled for completion and by 2012 a significant dip in activity will occur during the transition to the 'Legacy stage' of the construction process. However, most recent Olympic building programmes have resulted in some delays and, consequently, the programme should be regarded as a guideline only.

The largest project in value terms will be the construction of the Olympic Village with the bulk of spending in 2008 - 2009. The Olympic Stadium will also be a significant project. The majority of capital expenditure will be around the main Olympic site in East London, but there will be some investment in other parts of the UK.

One of the key reasons for the successful London bid was the Legacy element, whereby a particularly deprived neighbourhood would benefit significantly following the staging of the Olympics and Paralympic Games. Three major developments at Stratford City, Silvertown Docks and the Olympic Village are the centrepiece of the Legacy plans, totalling around 600 hectares of new residential, commercial, industrial and community facilities. The Legacy developments are set to begin immediately after the close of the Games and continue until 2020, reflecting substantial new build and RMI activity in this area over the next 15 years.

The key area of legacy investment will be the conversion of the Olympic Village into affordable housing as part of the regeneration of the Stratford area of East London.

4.11.2 Specification Issues & Attitudes

London's success in winning the Olympic bid has given a boost to the construction industry and is likely to result in high levels of demand for skilled construction workers. However, skills shortages are likely to be a significant problem for the Olympic construction effort as a whole and project managers are likely to seek new methods of overcoming this issue. As a result, there is likely to be a heavy emphasis on the use of MMC with a drive to off-site manufacturing and prefabrication to improve quality, value and timescales.

MMC is likely to be employed on a relatively large scale, particularly in view of the fact that a number of venues have been designated to be 'demountable' in order for them to be located in other parts of the country following the conclusion of the Games. London's Olympic construction programme includes several venues, which are temporary or include temporary elements with relocatable venues indicated to offer a 30% cost saving in terms of designing, procuring and constructing a new arena.

In using MMC, the London organising committee of the Olympic Games should be able to address issues concerning the availability of skilled workers, with buildings constructed off- site reducing the strain on the construction industry as a whole. Indications are, therefore, that demand for prefabricated buildings is likely to become increasingly prominent in Olympic construction over the next 2-5 years. This should benefit a wide range of suppliers in different product and material sectors, in terms of residential buildings, stadium construction etc., in concrete, steel and timber. In addition, the high level of site contracting work will also require a substantial number of temporary volumetric buildings for site storage, accommodation, security, office/administration facilities etc.

4.11.3 Potential for MMC

The key area of potential demand for MMC will be for the Olympic Village, itself by far the most significant area of newbuild expenditure, and will form part of the 200 hectare Olympic Park situated in Lower Lea

Valley in East London. It will cover 30 hectares with the design being developed by a leading international team of architects, engineering and landscaping specialists.

The Olympic Village will be built as a major regeneration project funded by a public and private sector consortium. No existing buildings are being used for the Olympic Village and the table below indicates the timescale for the development.

Table 22: Timescale for Construction of the Olympic Village	
Phase	Timescale
Start tendering for main contractor	Q2 2005 TO Q2 2006
Early phase infrastructure & demolitions	Q3 2006 to Q4 2007
Olympic Village Phase 1 on site	Q1 –Q4 2008
Main Olympic Village construction	Q3 2008 to Q4 2011
Source: London 2012	

The focus of construction of the Olympic Village will be on the accommodation of athletes, supporting personnel and officials. It is this area that is likely to offer the greatest opportunity for modular construction, underpinned by the 4-year construction schedule and the demand for repeatability. For the main Olympic Games, around 9,500 rooms comprising over 17k beds are to be built for the housing of the athletes. In addition, for the Paralympics, over 4,500 rooms with 9,000 beds are to be built.

In addition to the residential accommodation, there will be many other buildings located within the Olympic Park that are likely to lend themselves to modular construction: -

Residential Zone – main dining hall (10,000 m2, to seat up to 5,500 at any one time), casual dining areas (totalling 3,000 m2), staff dining hall (4,800 m2, to seat up to 1,500 at any one time), Chefs de Mission meeting hall, recreational areas, fitness centres, massage facilities, disco, the Polyclinic, retail centres and offices (for: the IOC, Athletes Commission and the World Anti Doping Agency)

International Zone – visitors welcome centre, VIP protocol welcome centre, media sub-centre, guest dining facilities, hairdressing facilities, telecommunications centre, banks, Internet centre, general stores, recreational and leisure facilities, retail outlets and the Olympic Museum.

Paralympic Village – 3 apartment blocks housing the Technical Officials, 10 apartment blocks for housing the athletes.

Outside the Olympic Village area, the largest building construction will be for the Media Centre. A new communications centre will be based on site and a fully equipped media centre will be established in the centre of London. A 2-storey 65,000 m2 and a single storey 45,000 m2 building will house the international broadcast centre and main press office. £113m will be spent on the provision of this centre and work will begin in February 2010, and will be completed within an 18 month schedule.

Other developments where we know MMC is to be used include the Basketball Arena and Handball Arena, Olympic Park – both these constructions will require a steel framed, lightweight clad, pre fabricated structure, with removable concrete pad foundations, bolted steel frames and pre cast concrete floors. The changing rooms will also be pre-fabricated and demountable.

5.0 Recommendations

In this section, we offer recommendations as how it should be possible to reduce site waste arising from traditional construction methods, in terms of the following:

- Types of MMC that we consider offer the best solutions for waste reduction and suppliers that have indicated an interest in working with WRAP or in marketing their products as having waste reduction benefits.
- End-user sectors that have already embraced MMC and which are anticipated to show growth over the medium-longer term
- Contractors that have progressive policies and systems in place for sustainable development, including site waste reduction and which have indicated experience of, or interest in MMC.

5.1 Recommendations for Waste Reduction

Table 23 summarises what we consider to be the key product and material waste streams that are typically generated by traditional construction methods and whereby the increased substitution of MMC is likely to make a contribution towards site waste reduction.

Table 23: Summary of Potential of Key Types of MMC for Reducing Site Waste

Solution ratings: 3 = significant reduction, 2 = moderate reduction, 1 = limited impact, blank = no reduction, or N/A = not applicable

	Packaging materials waste streams							Building product/material waste streams							
	Wood pallets	Shrink wrap	Card-board	Metal tins – paint, pres.	Plastic tubs & ,guns – mastics etc*	Plastic bags	Paper	Timber	Con-crete	Plaster-board	Panel prods.	Sheet or roll insulation.	Bricks, blocks tiles	Cement mortar plaster	Bldg services prods
Volumetric	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2
Timber frame	3	3	1	1	1	1	2	3	1	3	2	1	3	2	N/A
Pre-cast panels	3	3	2	1	1	1	2	3	2	2		3	3	3	N/A
Steel frame	3	3	2	1	1	1	2	3	3		1	3	2	3	N/A
SIPS/SIRPs	3	3	2	1	1	1	2	3	2		3	2	3	3	N/A
Composite panels	2	2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3	N/A	N/A	N/A
Pre-cast cladding	3	3	2	N/A	N/A		N/A	3	N/A	N/A	N/A	2	2	N/A	N/A
LSF (open)	3	3	2	N/A	2	2	N/A	3		N/A	3	1	3	3	N/A
LSF (closed)	3	3	3		2	2		3		N/A	3	3	3	3	N/A
Pods	3	3	3	2	2	2	2	1	1	2	N/A	1	2	2	2
Pre-cast structural			N/A	N/A	N/A	N/A	N/A	3	3	N/A	N/A	N/A	N/A	3	N/A
Insulating concrete formwork	2	2	N/A	N/A	N/A	N/A	N/A	2	2			2		3	N/A
Tunnel form	3	3	N/A	N/A	N/A	N/A	N/A	3	3	1	2	N/A	3	3	N/A

Source: AMA Research/ trade sources

Volumetric building systems are the ultimate in offsite manufacturing technology and their substitution for traditional building methods typically leads to a virtual elimination of all wastage bar excavation spoil for ground preparation. Based upon our case studies, we consider that the estimated waste reduction indicated in the table below is a reasonable overview of potential gains:

Table 24: MMC & Estimates of Waste Reduction though Substitution for Traditional Building Methods

MMC	Est. % reduction	Level of confidence
Volumetric building systems	70 - 90	Reasonable
Timber frame systems	20 - 30	Broad estimate
Concrete panel systems	20 - 30	Broad estimate
Steel frame housing systems	40 - 50	Broad estimate
OSB SIPS	50 - 60	Reasonable – depends on extent of prefabrication
Composite panels	20 - 30	Broad estimate
Pre-cast cladding	40 - 50	Broad estimate
LSF systems	40 - 70	Reasonable – depends on extent of prefabrication
Bathroom/shower & kitchen pods	40 - 50	Broad estimate
Pre-cast flooring	30 - 40	Broad estimate
Thin joint masonry	30 - 40	Broad estimate
Insulating concrete formwork	40 - 50	Broad estimate
Tunnel form construction	50 - 60	Broad estimate

Source: AMA Research/trade sources

However, with one or two exceptions no contractors or manufacturers have undertaken any assessment to compare the levels of waste reduction when substituting any form of MMC for traditional construction. During the course of our primary research, AMEC has been the only company able to provide any type of waste audit that can demonstrate waste savings either in the form of volume or value where using MMC products.

Therefore, the estimates we have provided are broad and are mainly based on our assessment of the key types of waste arising from particular construction activities. So, for example, the substitution of timber frame for brick and block construction will typically save on timber waste generated from in-situ roof construction and on block waste arising from the construction of the inner leaf. However, with most timber frame systems, the on-site installations of insulation, plasterboard, brick cladding and building services are still required, all of which are key waste streams, as are the associated packaging materials.

5.2 Recommendations for MMC By Key End Use Applications

The table below summarises those end-use sectors where MMC is mainly being used and also takes into account future developments where we anticipate there will be further growth in demand.

In terms of end-use application, the key drivers will continue to be:

MoD single living accommodation – over the next 6 years, Corus Living Solutions is supplying volumetric modules for SLA under the Project Allenby/Connaught PFI programme at sites around Salisbury Plain in Wiltshire and Aldershot. We also expect the continued use of volumetric modules, shower pods and light steel framing during the 2nd phase of Project SLAM. MoD Estates has been very encouraging in the use of MMC and in all areas of sustainable development, including waste reduction.

Other single living accommodation – we anticipate that the Government's requirements for fast-track programmes for affordable housing and keyworker living (KWL) will underpin growing demand for MMC -

such as volumetric and panellised modular building systems, kitchen and bathroom pods, LSF systems, SIPS, tunnel form construction and pre-cast products e.g. flooring, ICF and factory-clad composite panels. Similarly, the Government's drive to encourage more people into higher education is expected to underpin the requirement for additional student accommodation, which is likely to generate demand for the same types of MMC.

Prisons, detention centres etc – the current overcrowding crisis in the UK's prisons is expected to lead to additional fast-track construction of new prisons, which is likely to generate demand for MMC systems such as tunnel form construction, volumetric concrete *Quadblock* from Pre-cast Cellular Structures, pre-cast pods and pre-cast panellised systems. The other main area of MMC use has been the volumetric construction of immigration detention centres.

Private housing – to date the main type of MMC product used in this sector has been timber frame, while the use of other types of MMC product has been limited to date. However, the requirement for the fast construction of new housing may generate (further) demand for products such as bathroom and kitchen pods, light steel frames, SIPS, hollow-core flooring and ICF. Private housing represents a key sector to improve the level of MMC and make a major impact on reducing site waste levels. However, the main hurdle to overcome is the general reluctance among housing developers to embrace MMC.

Social housing – the Housing Corporation and several of the larger Registered Social Landlords, and contractors operating in this market, have demonstrated commitment to sustainable development and the use of MMC. To date, all types of MMC have been used to varying degrees in this market, with most of them being using on medium-high rise apartment blocks, although to a lesser extent on houses. However, we anticipate that many existing and emerging MMC technologies will be used on terrace housing as well as apartment blocks, in the wake of several recent schemes that have incorporated MMC.

Education – to date the use of MMC in the schools and higher education non-accommodation sector has been limited to the use of volumetric modules as temporary classrooms, classroom extensions, tuition blocks and shower facilities. To a lesser extent pre-cast panel systems and washroom pods have been used. The key potential for increasing the uptake of MMC in the schools sector rests with willingness among specifiers, working on the Building Schools for the Future schemes, to choose MMC, especially where there is a need for fast-track construction. There could be opportunities for the increased use of modular construction in general of school classrooms and higher education teaching blocks. Education represents a key opportunity in terms of scale of development programmes, current usage levels of MMC, Government influence in the procurement process and the ability to target key consortia of contractors and specifiers.

Table 25: Key Types of MMC by Main End User Sectors

Key: 3 = key markets; 2 = some current usage; 1 = potential use; blank = limited application

	Single living accommodation				Residential		Education		Healthcare			Leisure		Other			
	MoD	Stud. accom	KWL	Prison etc	House	Flats	Class-rooms	Other bldgs	S'con h'care	Prmry h'care	Care homes	Hotels	Other	Retail	Airprt bldgs	Arch'l	Ind/ Bus. pk
Volumetric	3	2	2	3	2	2	3	2	3	2	2	2	3	3	3		2
Timber frame		2	2		3	3		3		2	2		2			2	
Pre-cast panels	3	3	1	1	3	1	2	2		1	1	3	1	1			3
Steel frame	1		1		3					1	1	1	1	1			1
SIPS/SIRPs					3	3				1	1	1	1				
Comp. panels	1						2	2	3				3	3	3	2	3
Pre-cast clad						3		3	3			3		2		3	
LSF systems	3	2	1			3		2	3	1	1	3	1	1	2	2	1
Pods	3	3	3	3	1	3		2	2	1	2	3	2		2		
Pre-cast structural	3	2	2	3	3	3	2	2	3	3	2	3	2	3	3	3	3
ICF					1												
Tunnel form	1	3	1	1	1	1						3					

Source: AMA Research/trade sources

Notes**:**

1 – Education – 'classrooms' includes teaching blocks I, Other buildings includes shower blocks, pavilions, sports centres/gymnasiums

2 – Leisure – 'other' includes sports centres, pavilions, shower blocks, visitor centres

3 – Architectural – includes all types of bespoke, prestigious or high value end-user applications e.g. shopping malls, corporate head offices, luxury apartments

4 – Retail – refers to standardised construction e.g. forecourt stores, fast food outlets, retail park stores etc. Excludes bespoke e.g. shopping malls, dept stores

5 – Industrial, business and retail parks – covers all types of buildings typically located on these developments including industrial warehousing and retail 'warehouse' type stores

Healthcare – the NHS is another sector with vast potential for MMC. To date there have been several major hospital newbuild developments that have made use of a wide range of MMC products such as LSF systems, pre-cast cladding, pods and pre-cast components. The use of volumetric modules has mainly been limited to additional wards and temporary operating theatres. However, on the Continent, volumetric construction for large healthcare developments has been much more extensive. Over the longer term, as the Government is changing the focus away from secondary to primary healthcare, this could drive up the requirements for fast-track standardised MMC building solutions and, as with education, the sector represents a major target area in the medium term.

Leisure – the main sub-sectors driving demand for MMC have been the budget hotel, forecourt store and stand-alone fast food retail markets. The most widely used types of MMC have been volumetric construction, bathroom/washroom/shower pods and concrete cross wall systems. Further developments in the markets should both drive up demand for these types of MMC but also newer alternatives. In particular, tunnel form construction lends itself well to MMC. The London Olympic Games in particular is expected to drive up demand for MMC due to factors such as the requirements for fast-track construction of accommodation for athletes and dining/entertainment facilities for athletes and the general public.

5.3 Conclusion

It needs to be emphasised strongly that this is a scoping study and that recommendations here are not definitive. Nevertheless it is clear that the substitution of some MMC for traditional building methods do result in a net reduction in waste levels. That is, any waste generated in the manufacturing process is more than offset by reduced waste levels on site.

It needs noting that in some end-use sectors, the use of MMC is well established. In key private end-user sectors- e.g. hotels and student accommodation – demand is largely driven by the need for fast-track construction in order to minimise disruption to client activities and to generate revenues as quickly as possible. The need for minimal disruption is also a key benefit for the defence and education sectors.

The other main driver is that economises of scale can be achieved through the use of MMC on projects where there is a high level of repetition in terms of both design and number of units required. This is why single living accommodation is a key market.

However, there are some end-use sectors, notably PFI/PPP healthcare and schools design & build, retail newbuild and office newbuild, where the current use of MMC is limited, although we consider that there could be substantial potential in some sectors, though overcoming existing barriers may be relatively difficult in the short term.

Finally, the figure below provides a summary of the report findings and identifies which end-use sectors need encouragement or incentives to increase their use of MMC and which are self-motivated in this regard.

Table 26: Key Areas of Potential for Reduction of Site Waste though the Substitution of MMC

End users	Construction output 2006 - 2012	Current level of use of MMC	Potential for increasing uptake of MMC	Potential for waste reduction through increased use of MMC	Key drivers for MMC
MoD	Increasing substantially to 2012	Very high	Significant	Significant	MoD (Debut Services & Carillion) very pro-active. Requirements for fast-track construction & minimum disruption
Student accommodation	Expected to increase to at least 2012	Very high	Moderate due to current high usage	Significant	Requirements for fast-track construction & minimum disruption
NHS	Increasing substantially to 2020	Low - moderate	Substantial but dependent on specifiers	Significant	Main contractors e.g. Carillion, AMEC. Requirements for fast-track construction & minimum disruption
Schools	Increasing substantially to 2020	Low - moderate	Substantial but dependent on specifiers	Significant	Requirements for fast-track construction & minimum disruption
KWL	Increasing over short term	High	Significant	Significant	Affordable Housing
Social/Affordable housing	Increasing over longer term	High	Significant	Significant	Housing Assn, Affordable Housing, progressive builders e.g. Lovell
Private housing	Increasing over longer term	Low	Significant but dependent on clients & specifiers	Significant	NHBC, progressive builders e.g. Redrow, Taylor Woodrow
Prisons etc	Possible increase	High	Moderate – depending on Govt plans	Moderate - as MMC used	HM Prison Service policy on sustainable development
Hotels	Moderate over short term	High	Moderate due to current high usage	Moderate	Budget hotel sector-requirements for fast-track construction for early revenue generation
Retail	Moderate	Low - moderate	Moderate due to limited applications & low growth in sector	Moderate	Convenience store chain operators, fast food chain operators- requirements for fast-track construction for early revenue
Olympic games	Increasing substantially to 2011	N/a	Substantial – athletes accommodation	Significant	Requirements for fast-track construction + issues of labour availability

Source: AMA Research

6.0 Appendix

6.1 Product definitions

Composite panels – these comprise 2 rigid skins or leaves with a core material sandwiched between the sheet inner surfaces. The core material may consist of a polycarbonate stiffener, to permit bending round columns, architectural details, etc. or the core may comprise an insulating medium such as a plastics foam or mineral wool to increase thermal efficiency and reduce heat loss. Composite panel leaves are mostly manufactured from steel and to a lesser extent aluminium. Other materials include calcium silicate and high pressure laminates, with a growing sector represented by pre-cast concrete and glass reinforced concrete materials.

Hollow-core flooring – this comprises slabs made from pre-cast pre-stressed concrete elements with continuous voids provided to reduce self-weight and achieve structural efficiency.

Insulating concrete formwork - ICF has been developed as an alternative to the traditional method of setting ready mix concrete or concrete slabs and mortar inside a plywood frame. ICF systems are mostly formed from expanded polystyrene blocks separated by plastic or carbon-fibre spacers that lock together. They serve to create a cavity or mould for the structural walls of a building. Ready mix concrete is pumped into the cavity to form the structural element of the walls. Usually, reinforcing steel bars are added before concrete placement to give the resulting walls flexural strength, as in bridges and high-rise buildings made of concrete.

Light steel framing (LSF) systems - these are mainly supplied in standard length 'stick' format for site assembly and to a lesser, albeit increasing, extent as pre-fabricated frames/panels. Frame systems are supplied as open and closed formats. Open frames can be either be load-bearing, or non load-bearing, and are essentially bare frameworks. They are typically either supplied direct to volumetric modular building manufacturers or to site where they can be used as infill panels or for continuous façade construction.

Closed frames are factory-assembled units that are supplied to site, fitted with the drylining, insulation and sometimes the cladding components, depending on client requirements.

Pods – these are discrete 3-D units that are factory-fitted with building services equipment e.g. electrical circuitry, lighting and plumbing, sinks etc.. Unlike volumetric modules, pods do not typically part of the building envelope. The main application for pods is for bathrooms/shower units. To a lesser extent they are also used for kitchen units, public toilets and washrooms, bedrooms and combined units. Frames are usually made from concrete, steel or GRP. Concrete pods are typically load-bearing structures that are often installed into a building's structural concrete framework

Pre-cast concrete cladding – this comprises load-bearing or non-load bearing panels used for external wall cladding mainly made from pre-cast concrete but also available in reconstituted stone and glass reinforced concrete.

Pre-cast (concrete) panel systems – this term covers a range of proprietary systems that are now increasingly being supplied as panellised building systems. The key areas of application are the external walls, party walls and sometimes the basement walls. Several proprietary systems include insulated sandwich panels.

Steel frame building systems - comprise insulated external wall panels, party walls, flooring with some suppliers offering a roofing option. Some systems are also supplied fitted with external wall cladding, mostly brick slips. Current proprietary systems are all used for housing. Not to be confused with light (gauge) steel frames used for cladding support and infill panels.

Structural insulated panels (SIPS) – these are mostly, but not exclusively, oriented strand board (OSB) 'sandwich panels with cores of either expanded or extruded polystyrene (EPS) or polyurethane. Typically, panels and fabricated in factories and supplied in flatpack form to site. Being load-bearing structural products, SIPS are used to construct the external walls, party walls, flooring and roofing.

Structural insulated roofing panels (SIRPs) – pre-fabricated roof systems comprising insulated roof panels and the structural timber elements.

Thin Joint Masonry – this comprises aircrete blocks with tight tolerances and a specially developed mortar that is used in smaller quantities than standard mortar and dries much more quickly

Timber frame systems - the most commonly specified systems are open-frame comprising softwood vertical studs and horizontal rails, trussed rafters, wood-based panel sheathing, plasterboard lining and an external breather membrane. Ground floors can be of concrete or timber. Intermediate floors are of timber joists or prefabricated panels. Thermal insulation, internal vapour control membrane and lining are all installed on site.

Closed panel systems comprise the same components used with open frame systems but the addition of pre-installed insulation, protective membranes, linings and external joinery. Some top-end of the market systems also include the buildings services elements.

Tunnel form construction - a new form of MMC in the UK, specifically used for the construction of large-scale cellular buildings. Key end-use applications include student accommodation, standardised apartment blocks and terraced housing, prisons, hotels and barracks. It is essentially a formwork system that allows contractors to mould on-site the external wall, floor slabs and party wall elements simultaneously. They are particularly well suited to high-rise buildings of up to 40+ storeys and are commonly used in conjunction with other types of prefabricated elements such as pods and pre-cast cladding.

Volumetric modular buildings - off-site manufactured, fully assembled 3-dimensional modules, which are either used as 'standalone' units or are combined, by linking on-site, to form a complex of units, or alternatively to form a modular building, consisting of several linked and stacked units or modules with appropriate cladding features.

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