Offsite Manufacture in Australia

A Report on the current state and future directions of offsite manufacture in Australia

Industry Booklet 2005-004-C-03

Edited by Nick Blismas

The research described in this report was carried out by

Project Leader	Thomas Fussell
Team Members	Dr Nick Blismas
	Professor Ron Wakefield
	Peter Bullen
	Willy Sher
Researchers	Richard Bird
	Scott Brotherwood
Project Affiliates	Building Commission
	Curtin University of Technology
	John Holland Pty Ltd
	RMIT University
	Queensland Building Services Authority
	Queensland Department of Public Works
	University of Newcastle

Research Program C:

Delivery and Management of Built Assets

Project 2005-004-C:

Offsite Manufacture in Australia

Date Report Submitted:

CONTENTS

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

Off-site Manufacture (OSM) offers numerous benefits to all parties in the construction process. The uptake of OSM in Australia has however been limited.

There are numerous drivers of OSM in Australia. OSM was seen to: reduce construction time; simplify construction processes; provide higher quality and better control; provide high levels of consistency; produce products that are factory tried and tested; reduce costs when resources are scarce; reduce costs where work is in remote areas; result in improved working conditions; reduce onsite risks; alleviate skills shortages in certain centres; revitalise ‘traditional’ manufacturing regions; provide fewer trades and interfaces to manage and coordinate on site; reduce waste on and off site; improve housekeeping on site; facilitate the incorporation of sustainable solutions; and achieve better energy performance.

However, OSM also: result in longer lead-times; require designs to be fixed at an early stage; need to be designed for; be hindered by low IT integration in the industry; be impeded by the high fragmentation in the industry; be expensive when compared to traditional methods; have high set-up costs; possibly increase the consequences of incidents; have to cope with restrictive, fragmented, excessive, onerous and costly regulations especially between geographic jurisdictions; have to cope with a lack of codes and standards; have a negative stigma and attract pessimism based on past failures; meet resistance by unions; be restrictive and unable to deliver customer desires; be difficult to finance; result in loss of control on site and into the supply-chain; be limited by capacity of suppliers; be subject to inter-manufacturer rivalry and protection; attract low quality imports; be restricted by a lack professionals skilled in OSM; be restricted by manufacturers / suppliers lacking skills to enhance OSM efficiency; have sufficient industry investment in R&D; lack a knowledge portal; be subject to difficulties in inventory control; be constrained by site conditions; need to cope with difficult and expensive long distance transport for large, heavy loads; and be restricted by interface problems on site due to low tolerances.

Opportunities to exploit OSM exist within Australia. These include its application in high-density multi-residential complexes as well as the public sector (including hospitals, schools, prisons etc).

Technical areas for research and development into OSM were identified as walling systems, modularised housing and lightweight concrete wall panels. Furthermore, risk identification and mitigation strategies for OSM also need investigation.

An action-plan for driving OSM through the industry is presented. Initiatives largely revolve around skills training, education and knowledge provision.

1 INTRODUCTION

Off-site Manufacture (OSM) has long been recognised, both in Australia and internationally, as offering numerous benefits to all parties in the construction process. More importantly, it is recognised as a key vehicle for driving improvement within the construction industry. The uptake of OSM in construction is however limited, despite well documented benefits. This booklet reports on a project that determined the 'state-of-the-art' of OSM in Australia. It confirms the benefits and identifies the real and perceived barriers to the widespread adoption of OSM. Further the project identifies opportunities for future investment and research. Although numerous reports have been produced in the UK on the state of OSM adoption within their country, no prominent studies exist for the Australian context. This scoping study is an essential component upon which to build any initiatives that can take advantage of the benefits of OSM in construction. The Construction 2020 report predicted that OSM is set to increase in use over the next 5-15 years, further justifying the need for such a study. The long-term goal of this study is to contribute to the improvement of the Australian construction industry through a realisation of the potential benefits of OSM.

The study is published as two industry booklets:

Booklet 1 **Offsite Manufacture in Australia - A Report on the current state and future directions of offsite manufacture in Australia**

Booklet 2 **Offsite Manufacture in Australia - Offsite Case Studies**

The second booklet presents seven cases of the use of OSM products in Australia. Each case presents background to the project or company, before discussing the OSM aspects of the case. Each case ends with lists of benefits, barriers and lessons learnt from the project.

Within the scope of this project, the definition of 'off-site manufacture' has been left broad to incorporate a wide range of issues.

1.1 Structure of the booklet

The report consists of four sections. This first section outlines the objectives of the study, and provides a brief overview of the methods employed for data collection and analysis. Section two provides a brief introduction to off-site manufacture and findings from international studies. Section three presents the main drivers and constraints found through the Australian workshops, case studies and interviews. The concluding section (four) suggests opportunities for extending the use of OSM in the Australian Construction industry.

2 BACKGROUND

This section provides an overview of research initiatives undertaken in other countries, particularly the UK and United States. It distils and discusses the drivers, benefits, barriers and constraints of OSM found in the UK and US.

2.1 Findings from the UK and US

The Australian construction industry has recently identified off-site manufacture (OSM) as a key vision for improving the industry over the next decade (Hampson & Brandon, 2004). This echoes sentiments in other parts of the world, specifically the United Kingdom. However, no notable research or industry initiatives had been undertaken in Australia until the commencement of this scoping study.

Australian construction has been characterised as adversarial and inefficient; and in need of structural and cultural reform (Cole, 2003). Several UK Government reports have likewise called for significant improvement of the construction industry, which is likewise described as fragmented, adversarial and inefficient, requiring significant improvement (e.g. Latham, 1994; Egan, 1998). Significant similarities exist between these two construction industries. The reasons for the problems in the respective industries are complex, and require multiple, complimentary initiatives to ensure improvement. However, this call for efficiency and productivity improvements across these industries suggests that OSM has a major role to play. Indeed, the more recent UK government commissioned reports have proposed OSM as an important contributor to progress in the construction industry (e.g. Egan, 1998; Barker, 2004).

Given the high profile offered to OSM in the UK, activities to encourage the adoption of OSM in that industry is considerable, involving several research initiatives, communities of practice and government sponsored forums (e.g. Accelerating Change). Approximately £5 million had been invested by the UK government in research projects that included construction OSM between 1997 and 2001. This figure growing to £10 million when industry funding is taken into account (Gibb, 2001). Notwithstanding the consensus that OSM use will become significant in Australia (Hampson & Brandon, 2004), little coordinated effort has been made with almost no government investment. The review of literature is consequently concentrated on the UK, where the government's demonstrated interest over the past decade has stimulated extensive research in OSM.

Research in the UK has generally concentrated on case studies and anecdotal evidence, with a limited number of industry surveys or applied process mapping and improvement studies. These largely industry-level studies have produced an abundant array of benefits and barriers to OSM, with the hope that these would spur activity. Despite these well documented benefits (Neale *et al.*, 1993; Bottom *et al.*, 1994; CIRIA, 1999, 2000; BSRIA, 1999; Housing Forum, 2002; Gibb & Isack, 2003), uptake is limited. Goodier and Gibb (2004b) suggested that OSM accounted for approximately 2% of the £106.8bn UK construction sector in 2004. Initiatives are nevertheless ongoing, with Modern Methods of Construction (MMC) seen as an avenue for OSM adoption in sectors such as housebuilding (Barker, 2004; Goodier, Dainty & Gibb, 2004; Pan, Gibb & Dainty, 2005).

A major reason posited for the reluctance among clients and contractors to adopt OSM is that they have difficulty ascertaining the benefits that such an approach would add to a project (Pasquire & Gibb, 2002). The use of OSM, by many of those involved in the construction process, is poorly understood and based on anecdotal rather that data supported intelligence (CIRIA 2000). Given this, the UK industry's ability to appreciate the opportunities presented by OSM is hindered (Blismas *et al* 2005a). Some view the approach as too expensive to justify its use, whilst others view OSM as the panacea to the ills of the construction industry's manifold problems (Groak, 1992; Gibb, 2001).

To address this poor understanding of OSM, several different streams of research have emerged – two in particular are the 'case study' and 'added-value' approaches.

A large effort has focussed on presenting (positive) case studies of OSM within the construction environment. For instance BSRIA (1999) concentrated on mechanical and electrical services cases. Gibb (2001) included a series of case studies with some historical and contemporary examples of OSM ranging across all building types, from military installations, civil structures, airports through to modular office buildings. Most recently this case study approach of demonstrating successful uses of OSM has been further supplemented with a government-sponsored publication of 150 cameo case studies across all sectors of construction from residential through to civil and commercial (Buildoffsite, 2006).

The second stream of research has attempted to identify the value-adding aspects of OSM, so that the benefits could be better assessed and realised within projects considering adopting OSM. The Construction Industry Research & Information Association (CIRIA) conducted a research project entitled "Adding value to construction projects through Standardisation and Pre-Assembly" in 1999 in which the value gained from the application of OSM was reviewed. The reports concluded that a deliberate and systematic use of OSM, which commenced early in the process of the project, would increase predictability and efficiency, and ultimately add value to the process (Gibb 2001).

Further associated studies developed interactive tools for ascertaining the benefits of OSM. Blismas *et al* (2003) developed a tool enabling a comparison between traditional methods and OSM options, highlighting that a holistic evaluation would provide a more accurate and realistic assessment than is commonly used in the industry. A sample of the costing approaches used in six cases considering OSM demonstrated that most costing exercises simply take material, labour and transportation costs into account when comparing various options, often disregarding other cost-related items such as site facilities, crane use and rectification of works. (Blismas *et al*, 2006). These cost factors are usually buried within the nebulous preliminaries figure, with little reference to the building approach taken. Further, softer issues such as health and safety, effects on management and process benefits are either implicit or disregarded within these comparison exercises. Yet it is demonstrated that these issues are some of the most significant benefits of OSM. With this entrenched reductionist approach to costing, OSM will invariably appear more expensive than traditional methods. Other studies (Gibb *et al*, 2003) have looked at the health and safety risks associated with OSM. The issues in these UK studies are unlikely to be applicable to developing countries (Polat *et al* 2006), although highly relevant to the Australian industry.

Apart from the two streams described above, a third area that has not received significant attention is the application of manufacturing principles to construction. There have been some comparative studies undertaken with other industries; including steel, chemical material and manufacturing, where the latter's principles have been successfully used to produce attractive, customised and affordable homes in Japan (Gann 1996, Gibb 2001). However, many argue that these principles could be further applied to construction, particularly relevant to OSM. The following section briefly explores some aspects of manufacture.

2.2 Manufacturing principles

Offsite manufacture is used for several different reasons. At times it may be forced on a construction project due to restricted site access or time constraints, however OSM is largely seen as offering the ability to produce high volume, high quality products based on the efficiencies of general manufacturing principles common to many industries. These perceptions are supported by US research (unpublished research under review) showing that offsite production consistently shows higher productivity growth than onsite production. Despite this evidence of greater efficiency and productivity, it appears the principles are generally ill-understood.

Basic manufacturing concepts

The industrialisation aspects of OSM are often implicit in the research or discussion of the topic, giving the impression that these principles are applied and universally understood, however construction OSM is still largely immature in manufacturing terms. Industrialisation, the broader term that incorporates manufacture, encompasses many different concepts and initiatives. The PATH project (2002) summarised some examples of industrialisation concepts that have been successful in other industries and that may have application in construction. Briefly these include (but are not limited to):

- Just-in-time (JIT) manufacturing that includes effective supply chain management;
- Flexible, agile, lean production systems;
- Concurrent engineering and design for manufacturers that use various techniques and processes to enhance the manufacturability of the product;
- Manufacturing requirements planning (MRP), manufacturing resource planning (MRP II), and enterprise resource planning systems (ERP), which are processes that are enabled by information technology;
- Concurrent design, where communication among designers and the producers (construction foremen, site supervisors, trade contractors) can significantly improve the efficiency of production;
- Time- and space-based scheduling that facilitates keeping track of who is where, doing what, and when. This type of scheduling is especially appropriate for construction activities, as crews move among sites.

Some aspects of all of these have been adopted to some extent in construction. JIT and concurrent engineering have received notable attention in construction although mainly regarding on-site works. Two other areas where manufacture and construction have converged regard product modelling and lean construction.

The first is ***Building Information Modelling*** (BIM) which describes the virtual modelling of products, with all associated information within a single model. BIMs can contain numerous dimensions including spatial, geographic, material, component, lifecycle performance and workflow information. The American Institute of Architects simply define BIM as "a model-based technology linked with a database of project information". Essentially it allows information to be linked into the building model. This can take the form of geometrical, non-graphical and other information. The wealth of information contained within or linked to BIMs allows the possibility for direct interfacing between designers, suppliers, manufacturers and users. This offers future CAD/CAM-type possibilities for the construction industry that can interface directly with OSM.

The second area of convergence is ***Lean construction*** (LC) which seeks to adopt lean production methods into construction. It has established itself in certain sectors of construction, although is not yet widespread. The manufacturing principles underpinning LC lend themselves well to OSM (see for example Ballard & Arbulu, 2004, for lean concepts and OSM). Its core concepts are encapsulated by Roy *et al* (2003) and are:

- specify work value in the eyes of the customer;
- identify the value stream and eliminate waste;
- make value flow at the pull of the customer;
- involve and empower employees;
- continuously improve in the pursuit of perfection.

These five core concepts can be articulated into two simpler principles, namely 'efficiency' and 'flexibility'. 'Efficiency' describes an understanding of value, the elimination of process and material waste, the synchronisation of supply-chains, and the continuous improvement of process and product. 'Flexibility' alludes to delivering customer-controlled solutions – both now and in the future. The rigidity of production processes is increasingly seen as a hindrance, and is stimulating further development for flexible delivery in manufacture. Further, flexibility in the use of the product into the future is equally drawing attention (sometimes referred to as 'open buildings'). Future OSM solutions will need to embrace both of these aspects.

Efficiency and flexibility

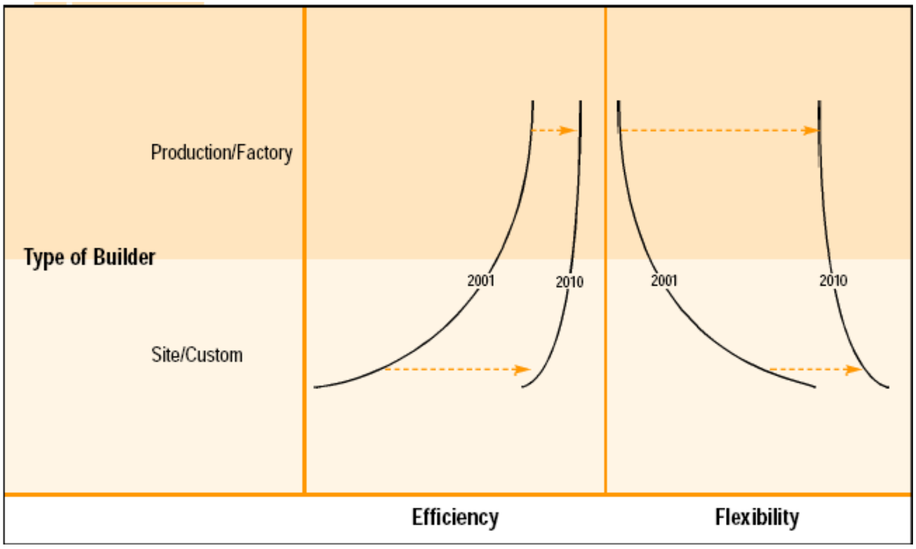
The tension that has naturally existed in manufacturing is that between volume and choice. High volumes and therefore economies of scale have naturally precluded variance amongst products, limiting customer choice. Manufacturers in construction have long argued that large volumes of the same product are needed to ensure viability. Standardisation has therefore been put forward as an enabler of construction OSM. However, to ensure there is a stable demand for standardisation, either choice needs to be limited or demand needs to be increased. Both options have inherent problems as viable strategies.

The drive to combine standardisation with systematic building practice has grown alongside the development of the off-site fabrication shops and the factory-based building component industry (Groak 1992). However the struggle to resolve the conflict between uniformity and variation, and between maximum standardisation and flexibility still continues to be a source of tension. The requirement for standardisation to include interchangeability of components highlights that it is the interfaces between the components that is important, rather than the components themselves (Gibb 2001). Future developments in non-construction manufacturing and OSM will be the replacement of mass production with mass customisation. Customer's needs and desires will be important drivers for such customisation, however a reliable and responsive supply chain with short lead times will be essential for an efficient customised solution (Roy *et al* 2003).

The future

This view has been adopted by PATH (2002), in which they called for increasing industrialisation in US house building towards the year 2010, mainly targeting an increase in flexibility. Figure 2.1 below illustrates this concept, showing the shift required in the decade to 2010, calling for manufactured housing to improve in efficiency, but most importantly to make marked strides in offering flexibility that is currently enjoyed by site-based construction. OSM needs to deal with this trend if it hopes to make inroads into the construction industry.

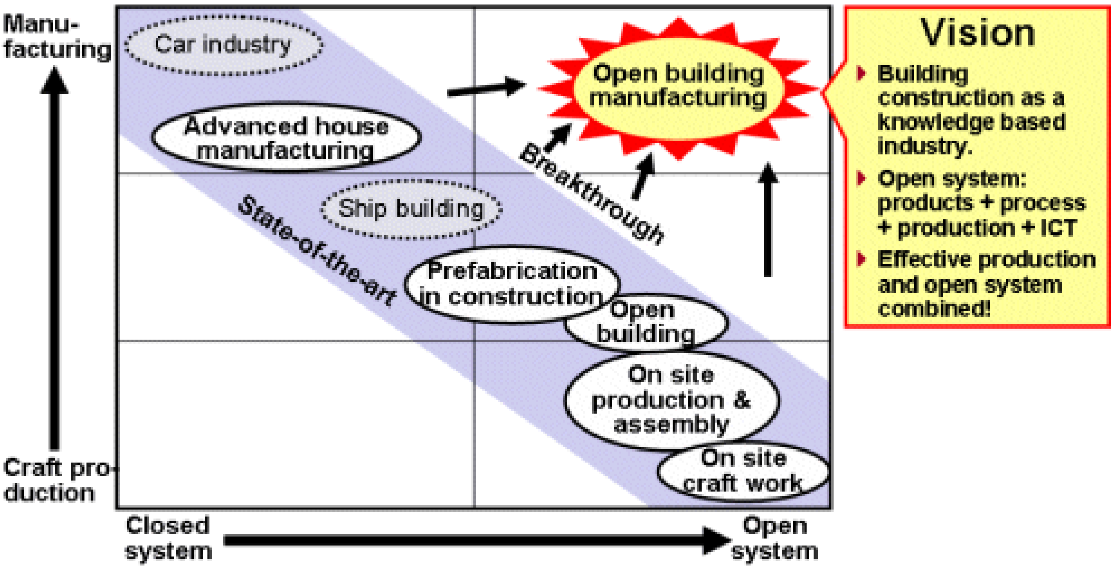
Figure 2.1: Industrialising the house building process (PATH, 2002)



Source: Technology Roadmap: Whole house and Building Process Redesign, PATH (2002)

Another representation of this idea is communicated by Manubuild (2007) in Figure 2.2, who illustrate the state-of-the-art in construction manufacture showing the array of sophistication across all types of construction delivery. Whilst manufacturing (i.e. efficiency) aspects are well understood by some sectors, such as advanced house manufacturing, the systems are closed (i.e. inflexible). Generally the more traditional methods of construction are open and flexible yet are bespoke and inefficient. The challenge facing the advance of construction is to break through to 'open building manufacturing' that combines highly efficient manufacturing in factories and on sites, with an open system for products and components offering diversity of supply in the market (Manubuild, 2007). These views echo those mentioned above, essentially efficiency combined with flexibility. OSM therefore must embrace this view if it has any hope of succeeding in the future.

Figure 2.2: Open building manufacturing (Manubuild, 2007)



Source: www.manubuild.net, 2007

The review of other work on OSM provides a basis for understanding and comparing the Australian construction industry. The next section summarises the drivers and constraints of OSM use in Australia.

3 OFF-SITE MANUFACTURE IN AUSTRALIA

This section begins by presenting the drivers and constraints of OSM in Australian construction.

3.1 Drivers and benefits of off-site manufacture

The drivers and benefits of OSM as described by respondents were distilled into Table 3.1 below.

Table 3.1: Drivers of OSM in Australia

Drivers	Description	Comments and notes	Action
Process & Programme	- Reduces construction time - Simplifies construction process	Significant contributor to reducing whole cost of construction, e.g. - lower site-related costs for constructors, - earlier income generation for clients	Benefits of speed of construction need to be emphasised
		Quicker completion reduces site disruptions and hazards, e.g. - decreased road closures etc.	
Quality	- Higher quality and better control in the factory - High levels of consistency - Product tried and tested in the factory	Product testing allows for better control of safety factors/margins	Use this to mitigate negative sentiments about OSM (see constraints)
		Can deliver better product quality, consistency, component life, reduced whole-life cost and defects through QA in controlled factory environment. e.g. - level of accuracy for steel fabrication better offsite - better surface finish achievable for precast concrete which is not being covered - some products offer 100 year design life unlike in-situ - Can achieve better surface finish	
		Design can be refined in manufacture to improve quality	
		Enables new/different materials and processes to be used, e.g. - elaborate surface definitions/colours/textures can be easily specified and precast	
Cost/Value/ Productivity	- Lower costs where work is under resource pressure - Lower costs of workforce in remote areas - Lower whole cost of construction	Costs related to material and labour force pressures drives OSM, e.g. - trade skills shortages such as bricklayers - reduced supply of formwork in Queensland - brick shortage in WA	Whole-life cost needs to be emphasised with understanding of value rather than purely direct material/labour costs
		Allows for more efficient designs that reduce need for high safety margins and specifications	
		Reduced labour/trade living expenses in remote areas	
		Significant contributor to reducing whole cost of construction, e.g. - lower site-related costs for constructors, - earlier income generation for clients	

Drivers	Description	Comments and notes	Action
People & OHS	- Improved working conditions for labour - Reduced onsite risks due to lower likelihood and exposure	Improved working conditions for workers, controlled environments to protect workers from elements such as rain, high temperatures etc.	Take advantage of positive work benefits OSM can provide to a workforce to promote OSM
		Reduces OHS risks onsite due to - reduced time on-site - reduced likelihood due to lower hazard exposure, e.g. open hole in sewage pipe-laying reduced - fewer trades and people on-site	
		OHS risks can be better controlled in factory environment - OSM could be driven if increased responsibility is put on designers for OHS	
		OSM gives sense of job security, not reliant on variable subcontractor work with a more stable workforce an better loyalty - Work ethic reported as very low in SE Qld due to high volume of work. High staff turnover, absenteeism and low loyalty	

Skills & Knowledge	- Significant shortage of skilled trades in construction, being acute in certain centres - Revitalisation of 'traditional' manufacturing regions with high unemployment	Site skills/knowledge: - Low skills bases in remote areas of the larger states - Shortage of trade skills a major driver for OSM o fewer trades needed in OSM environment o reduce risk in 'boom' times with shortages o during shortage, it is difficult to find good tradesman and exposes poor tradesman o systems that require lower skills may be favoured (e.g. steel frames), likening to 'mecano-set' mentality Skills shortages identified in WA include: - bricklayers; - form workers; - plasterers; - carpenters; and shop detailers	Importation of 'cheaper' labour suggested by respondents as possible with new IR laws; but hesitance expressed due to problems from Unions Skills training
		Offsite skills/knowledge: - Can revitalise manufacturing sectors in 'traditional manufacturing' areas that have lost their industries o benefits especially in areas of low skills where labour costs are low improves local skills base	

Drivers	Description	Comments and notes	Action
Logistics & Site Operations	- Fewer trades and interfaces to manage and coordinate onsite - Ability to transport large loads easily	Fewer trades on site aid coordination and reduce interfaces	Demonstrate process improvements and interface reductions
		Ability to build and transport increasingly large components for delivery to (remote) areas without trade base, skills or facilities, e.g. - 100 tonne bridge beams for remote areas	
		Enables better trade coordination	
Environ'l sustain'y	- Waste reduced on and off site - Better housekeeping due to removal of trades - Sustainable solutions better incorporated through design - Can achieve better energy performance	Building and especially on-site waste (up to 40% of landfill) can be reduced by OSM, e.g. - one case used waste from manufacture to fuel site one pre-caster claims all steel and concrete recycled with no waste	Demonstrate that better efficiency ratings due to better dimensional tolerances are possible Demonstrate sustainability benefits
		The Building Codes of Australia Section J – Energy Efficiency (ANCN 2007b) expected to drive greater OSM use due to better ability to design performance of panels	
		Cleaner sites due to decreased on-site wet-trades	
		OSM is innovative in material and design and therefore can incorporate sustainable solutions including easier re-use and recycling after useful life	
Other	- Quick response housing for emergency/natural disasters	OSM items such as homes/cabins can be stored as stock. This would give an improved response in times of need - to get the products onto site and in use in as short time as possible etc.	Requires government policy for this driver to be operational

3.2 Constraints and barriers of off-site manufacture

The constraints and barriers of OSM as described by respondents were distilled into Table 3.2 below.

Table 3.2: Constraints of OSM in Australia

Constraints	Description	Comments/recommendations	Action
Process & Programme	- Longer lead-times - Inability to fix design without further changes - OSM must be designed in, not retrospectively - Low IT integration in the industry - High fragmentation in the industry	Design process is based on traditional mode and is unsuited to OSM Requires more pre-planning on a project, suggested that lead times required may nullify any overall time advantages Generally low level of IT integration in construction – high levels of integration make OSM efficient Advantage only possible if facility designed for OSM, not fitted retrospectively Does not permit changes, as these are expensive once manufacture has commenced Knock-on effects of problems in the manufacture process can be significant	Disciplines and processes need to be streamlined using integrated IT systems. Including development of IT based project management system to coordinate subcontractors and integrate the process. Need to learn from other industry's systems – from design through order and production, giving - Improved design tools - Better engineering solutions - Easier control and specification - Just in time capabilities - Fully integrated billing and payment – time and materials - More accurate production Information and document distribution and management protocols required in high IT environment, so as not to overload Storage and ownership of digital information should be addressed Client needs to decide with team to design OSM into the project from concept stage, however client may be more interested in functionality rather than method of delivery
Cost/Value/ Productivity	- Seen as expensive when compared to traditional methods - High initial and set-up costs	Seen as expensive when compared to traditional methods High initial set-up costs OSM seen to increase design fees Cranage costs can be high Transport costs interstate or over distance costly and can negate any advantage	A system or method is required to objectively ascertain the benefits of OSM Demonstrate that OSM systems should reduce design fees as these are 'written-off' within the product
People & OHS	- May increase consequence of incident	Need for crane has safety issues associated with large loads etc.	Perhaps use screen lifting and self-climbing cranes

<table>
<tr><th>Constraints</th><th>Description</th><th>Comments/recommendations</th><th>Action</th></tr>
<tr><td rowspan="4">Regulatory</td><td rowspan="4">- Restrictive, fragmented, excessive, onerous, costly regulations especially between jurisdictions
- Few codes and standards available</td><td>Australian Building Greenhouse Rating (ABGR) only attributes 20% of the building to energy
- Energy ratings not affected by OSM as measured at the design stage on the building rather than the construction process
- Section J can be used to encourage more OSM components</td><td rowspan="4">Energy rating systems to be used to demonstrate that OSM can <u>exceed</u> current standards

Regulators (e.g. BCA) need to look at (pre-cast), accreditation for OSM skills

Regulators need to look at (pre-cast) introducing separate section to code for pre-cast

Changes to fire engineering standards could be re-thought to open the steel market</td></tr>
<tr><td>Legislation and qualifications unclear for pre-casters (versus concreter). Appears concreter needs more qualifications with manufacturing and installing tilt up than a civil engineer with experience in manufacturing and installing pre-cast</td></tr>
<tr><td>Inadequate Codes for OSM varieties, e.g.
- addresses tilt-up but not other pre-cast products</td></tr>
<tr><td>Inconsistency between local and shire legislation and interpretations, e.g.
- difficulty getting sign-off on electrical or plumbing systems in different areas not familiar with system</td></tr>
<tr><td rowspan="6">Industry & Market Culture</td><td rowspan="6">- Negative stigma and pessimism of OSM due to past failures
- Resistance by unions to changes
- OSM seen as restrictive and unable to deliver customer desires
- Difficulty obtaining finance</td><td>Unionised labour market limits flexibility OSM can give. General resistance to offsite work, although this resistance seems to be diminishing</td><td rowspan="6">Different approaches required to market commercial and residential products

Annual OSM products and careers expo to showcase and promote OSM, trade shows and seminars

Changes to tertiary education - emphasis on future trends and OSM for engineers, architects and CMs

Emphasis should be on mass customisation rather than mass production, includes increased standardisation but not necessarily repetition

Improve government standards for civic architecture intended to improve building quality and longevity, thus, showcasing OSM products in operation and dispelling negative perceptions

Establish government funded display centres showcasing OSM products in use</td></tr>
<tr><td>Client's desire for particular structures or traditional finishes may inhibit OSM, e.g.
- double-brick housing in WA</td></tr>
<tr><td>'The whole industry is conservative' Resistance to change by contractors, suppliers and professions</td></tr>
<tr><td>Design options seen as too limited</td></tr>
<tr><td>Negative stigma from failures or perceived low-quality products, e.g.
- poor pre-cast systems from post-war through to 1960s
- 'transportables' for schools, mining and harsh remote climates
- bad experiences with 'cowboy' suppliers</td></tr>
<tr><td>Difficulty obtaining finance from institutions more familiar with traditional approaches</td></tr>
</table>

Constraints	Description	Comments/recommendations	Action
Supply-chain & Procurement	- Loss of control onsite and into the supply-chain - Limited supplier capacity - Inter-manufacturer rivalry and protection - Low imported quality	Control of supply-chain, especially interstate and international is high risk Capacity to supply OSM products is limited (severe in places such as WA where industry is small and rely on east with high transport costs) Importation of OSM products prone to low quality and non-compliance to Australian standards Potential loss of project control, especially onsite Different payment terms and cash-flow arrangements required for OSM Market protection from traditional suppliers	Assembling project team early in the process (e.g. alliance or D&B) improves relationships and improves OSM success Manage, inspect supply-chain actively
Skills & Knowledge	- Lack of skills by professionals in OSM with subsequent effects on the entire process - Lack of skills in manufacturers/ suppliers to enhance OSM efficiency - Lack of industry investment in R&D - Lack of knowledge repository, portal	Professional skills/knowledge: - Limited expertise in the marketplace by designers and constructors - Design philosophy is based on traditional methods that are unsuited to OSM - Finer design skill and understanding is required to ensure interfaces are managed and designed - Education and training still focussed on current practices, not future ideas Site skills/knowledge: - Requires higher onsite skill to deal with low OSM tolerances for interfaces - May necessitate higher levels of IT literacy which is low in SMEs Offsite skills/knowledge: - Pre-casters uncomfortable with new technologies/systems of OSM, qualifications are not adequate or transferable. Reliance is currently on supplier to train contractors to install correctly - Particular OSM specific skills are limited, e.g. logistics management, coordination of OSM installation, erection skills Industry knowledge: - General lack of guidance and information on OSM available in the market-place. Lack of single information source, rely on experience. Particularly disadvantages SMEs - Lack of R&D in OSM	Focus on future trends and ideas for CMs, Engineers and Architects, as well as students of these disciplines Funding to attend conferences/meetings needs to be encouraged Improved research incentives to stimulate local innovation and start-ups A whole philosophy change is needed – a paradigm shift. Design research for developing innovative integrated designs Increase appeal for manufacturers to employ apprentices Better skills training to address requirements Locate manufacture plant in areas with suitable labour source Conduct career days at schools to interest people in the OSM market Portal for international trends, products and processes, especially in WA Market research needed to ascertain opportunities

Constraints	Description	Comments/recommendations	Action
Logistics & Site Operations	- Difficulties in stock/inventory control especially with large heavy products - Site conditions can constrain OSM use - Transport difficult and expensive for long distance and large, heavy loads - Interface problems on site due to low tolerances	Production facility logistics and stock management difficult, especially with large concrete products Site specific constraints include: - limited access on site for manoeuvre - limited or restricted access to site for delivery - access of cranage to site - scale of the facility/structure - size of components Crane use vulnerable to stoppages, that are high risk for OSM, e.g. - crane driver stoppage, - high winds - hook time availability Transport of large components limited due to: - load/mass of item - road widths - bridge load capacities - transport curfews - requirement of escorts at great expense E.g. Road travel restrictions (NSW): - 2.5-3.5m can only travel between the hours of 09:00 and 15:00 - 3.5-4.5m must have an escort vehicle - 4.5m + must have a police escort – which has massive costs High mass of PC concrete products results in higher transport costs Low tolerances increase problems when fitting components onsite	Bar coding or RFID (radio frequency identification) management is crucial to help identify where parts are all the way along the supply and construction phase. RFID also allows for a 'birth certificate' so any item can be tracked back at any point in the building's construction and life If possible locate manufacturing plant close to the project to reduce transport costs and logistics

4 THE FUTURE OF OSM IN AUSTRALIA

Given the drivers and constraints of OSM in Australian construction, a suggested action-plan for the industry is provided below. This furnishes the industry with a basis for formulating a series of research projects and initiatives to promote or facilitate OSM in construction. This section speculates on the opportunities, initiatives and paradigm shifts necessary for OSM to become entrenched within the Australian construction industry.

Table 4.1: Action Plan for OSM in Australia listed in order of relative priority

Theme and Actions
1. Skills & Knowledge Skills training in trades and OSM skills required to ensure the industry is well furnished; Regular conferences/meetings should be arranged to demonstrate OSM projects and benefits; Encourage government to provide improved research incentives to stimulate local innovation and business start-up; Increase appeal for manufacturers to employ apprentices; Encourage location of manufacturing plants in areas with suitable labour source; Conduct career days at schools to interest people in the OSM market; Create online portal to disseminate international OSM trends, products and processes OSM; Conduct market research study to ascertain market opportunities.
2. Process & Programme Disciplines and processes need to be streamlined using integrated IT systems. Including development of IT based project management system to coordinate subcontractors and integrate the process. Need to learn from other industry's systems – from design through order and production; Advice on information and document distribution and management protocols required in high IT environment; Advice on storage and ownership of digital information should be addressed; Encourage design of OSM into the project from concept stage through education and showcasing.
3. Industry & Market Culture Establish annual OSM products and careers expo to showcase and promote OSM. Include trade shows and seminars; Commence initiatives to ensure that tertiary education focuses on future trends and ideas including OSM and manufacturing (CM, engineers and architects); Marketing emphasis should be on mass customisation rather than mass production, includes increased standardisation but not necessarily repetition; Improve government standards for civic architecture intended to improve building quality and longevity, thus, showcasing OSM products in operation and dispelling negative perceptions. Showcasing will demonstrate all benefits of OSM; Establish government funded display centres showcasing OSM products in use.
4. Cost/value Whole-life cost needs to be emphasised with understanding of value rather than purely direct costs. A system or method is required to show and convince clients that OSM is beneficial.
5. Regulatory Energy rating systems to be used to demonstrate that OSM can <u>exceed</u> current standards; Appropriate authorities need to examine the potential for OSM skills accreditation; Appropriate authorities need to examine introduction of separate section to code for pre-cast.
6. Logistics & Site Operations Inventory management research and advice necessary for manufacturers; Advise on location of manufacturing plant close to the project to reduce transport costs and logistics.
7. Environmental sustainability Demonstrate that better efficiency ratings due to better dimensional tolerances are possible; Demonstrate sustainability benefits.

REFERENCES

Ballard, G. and R. Arbulu, "Making Prefabrication Lean," 12th Annual Conference of the International Group for Lean Construction, Elsinor, Denmark, August 2004, pp. 629-642.

Barker, K. (2004), Review of Housing Supply, ODPM, UK.

Blismas, N.G., Pasquire, C.L., Gibb, A.G.F. and Aldridge, G.B. (2003) *IMMPREST - Interactive Method for Measuring Pre-assembly and Standardisation benefit in construction*. (CD format) Loughborough University Enterprises Limited, Loughborough University, UK, ISBN 0-947974-13-X.

Blismas, N.G., Gibb, A.G.F. and Pasquire, C.L., 2005b, "Assessing project suitability for offsite production", The Australian Journal of Construction Economics and Building, Australian Institute of Quantity Surveyors, 5(1), July pp. 9-15, ISSN 1445 - 2634.

Blismas, N.G., Pasquire, C.L. and Gibb, A.G.F. (2006) Benefit evaluation for off-site production in construction. *Construction Management and Economics*. **24**, 121-130.

Blismas, N.G., Pendlebury, M., Gibb, A., & Pasquire, C., 2005a, Constraints to the use of Off-Site Production on Construction Projects , Architectural Engineering and Design Management (1) 153 - 162

Bottom, D., Gann, D. Groak, S. and Meikle, J. (1994) *Innovation in Japanese Prefabricated House-Building Industries*, Construction Industry Research and Information Association, London.

BRE factsheet 2004, Modern Methods of Construction: BRE presents the arguments in favour of off-site production, UK

BSRIA compiled by Wilson, D.G., Smith, M.H. and Deal, J. (1999) *Prefabrication and Pre-assembly – applying the techniques to building engineering services*. Briefing note ACT 2/99, The Building Services Research and Information Association, Bracknell.

Builoffsite, 2006, Cameo Case Studies. Discovering offsite (www.buildoffsite.com), UK.

CIRIA, and principal author Gibb, A.G.F. 2000, Client's Guide and Toolkit for Optimising Standardisation and Pre-assembly in Construction, Report CP/75, Construction Industry Research and Information Association, London.

CIRIA, compiled by Gibb, A.G.F., Groak, S., Neale, R.H. and Sparksman, W.G. 1999, Adding Value to Construction Projects through Standardisation and Pre-assembly in Construction, Report R176, Construction Industry Research and Information Association, London.

Cole, (2003), *Final Report of the Royal Commission into the Building and Construction Industry, v6 Reform – Occupational Health and Safety*, Commonwealth of Australia, Canberra.

Egan, J. (1998) *Rethinking Construction*, The Egan Report, Department of the Environment, Transport and the Regions.

Gann, D., 1996, Construction as a Manufacturing Process – similarities and differences between industrialised housing and car production in Japan, Construction Management and Economics (14) pp 437 – 450

Gibb, A.G. (1999), Off-site fabrication - pre-assembly, prefabrication and modularisation, Whittles Publishing Services, pp.262, ISBN 1 870325 77 X.

Gibb, A.G.F., Haslam, R., McKay, L.J., Pendlebury, M. and Blismas, N.G. (2003) *HASPREST – Health, safety and accident causality issues in construction pre-assembly and standardisation*. (CD Format) Dept of Civil and Building Engineering, Loughborough University, UK, ISBN 0-947974-16-4.

Gibb, A.G.F and Isack, F. (2003) Re-engineering through pre-assembly: client expectations and drivers. *Building Research & Information*, **31**(2), 146-160.

Gibb, A.G.F. 2001, Standardisation and pre-assembly - distinguishing myth from reality using case study research, Construction Management and Economics, 19, 307–15.

Goodier, C.I. and Gibb, A.G.F., 2004a Barriers and Opportunities for Off-Site Production, October pp. 75, DTI, ISBN 1 873844 57 3.

Goodier, C.I. and Gibb, A.G.F., 2004b, The value of the UK market for offsite. DTI: Buildoffsite, UK.

Goodier, C.I., Dainty, A.R.J. and Gibb, A.G.F. 2004, Manufacture and installation of offsite products and MMC: Market forecast and skills implications, May 44 pp, Report for CITB Construction Skills.

Groak, S. 1992, The Idea of Building, E & FN Spon Routledge, London.

Hampson, K. and Brandon, P. 2004. *Construction 2020: A vision for Australia's property and construction industry*. Cooperative Research Centre for Construction Innovation for Icon.Net Pty Ltd. ISBN 0 975097725. Brisbane, Australia.

Housing Forum (2002) *Homing in on Excellence – A commentary on the use of off-site fabrication methods for the UK house building industry*, Housing Forum, London.

Latham, M. 1994. *Constructing the team*, Final Report, HMSO, UK.

Manubuild, 2007, www.manubuild.net, viewed 2nd April 2007.

Neale, R.H., Price, A.D.F. and Sher W.D. (1993) *Prefabricated modules in construction: a study of current practice in the United Kingdom*. Ascot: Chartered Institute of Building.

Pan, W., Gibb, A.G.F & Dainty, A. 2005, Offsite Modern Methods of Construction in Housebuilding: Perspectives and Practices of Leading UK Housebuilders. Loughborough University, Loughborough, UK.

Pasquire, C.L. and Gibb, A.G.F. 2002, Considerations for assessing the benefits of standardisation and pre-assembly in construction, Journal of Financial Management of Property and Construction, 7(3), 151–61.

PATH, 2002. *Technology Roadmap: Whole House and Building Process Redesign, One year Progress Report.* Partnership for Advanced Technology in Housing (PATH), Prepared for

U.S. Department of Housing and Urban Development, Office of Policy Development and Research, Washington, D.C, USA.

PATH, 2004. *Technology Roadmap: Advanced panelised construction, 2003 Progress Report.* Partnership for Advanced Technology in Housing (PATH), Prepared for U.S. Department of Housing and Urban Development, Office of Policy Development and Research, Washington, D.C, USA.

Polat, G., Arditi, D., Ballard, G., Mungen, U., 2006, Economies of on-site versus off-site fabrication of Rebar, Construction Management & Economics (24) 1185-1198.

Roy, R., Brown, J., Gaze, G., 2003, Reengineering the construction process in the speculative house-building sector, Construction Management & Economics (21), pp137-146

GLOSSARY

SIPS	Structural Insulated Panels
ICF	Insulated Concrete Forms
PATH	Partnership for Advancing Technology in Housing
OSM	Off-site Manufacture
OSP	Off-site Production

AUTHOR BIOGRAPHIES

Richard Bird

Research Associate, School of Property, Construction & Project Management, RMIT University

Richard has an Honours Degree in Industrial Design (Eng) and a post Graduate Diploma in Ergonomics. He has worked for 10 years as a consultant Ergonomist at ICE Ergonomics in the UK (now ESRI), working in many areas including the safety of consumer and industrial products. This work was approximately equally divided between Research and commercial work. The Research work was mainly large scale Government funded research, predominantly relating to the safety of products. More recently Richard has been working in the commercial sector developing new concepts and products predominantly within the toy industry. Since coming to Australia Richard has been involved as a researcher on two CRC projects though his work at the School of Property, Construction & Project Management, RMIT University.

Nick Blismas

Senior Lecturer, School of Property, Construction & Project Management, RMIT University

Nick is a Senior Lecturer in the School of Property, Construction & Project Management, having joined RMIT University from Loughborough University (UK) in February 2004. His main research fields are: construction OHS; multi-project and programme management; and off-site production. His research has always been industry focussed, involving significant numbers of collaborating organisations. In addition to his 10 years construction management research experience, both in Australia and the United Kingdom, Nick also has 3 years industry experience as a project manager.

Scott Brotherwood

Research Associate, Department of Construction Management, Curtin University of Technology

Scott is a third year Urban and Regional Planning student and sessional tutor with Curtin University's, Bentley Campus. A keen advocate of sustainable development, he has previously been involved with Alcoa's Stronger Communities and intends his thesis studies to centre on social capital and local economic development. Recognised by the UDIA for his exemplary work in local planning Scott excels in his academic stream.

Peter Bullen

Lecturer, Department of Construction Management, Curtin University of Technology

Peter Bullen is a lecturer in project management, environmental management, sustainable development and construction technology in the Department of Construction Management in the Faculty of the Built Environment, Art and Design at Curtin University of Technology. He has over thirty years of experience in private and public sector commercial and residential construction project management, quantity surveying and facility management in the UK, Europe and Australia. Peter is currently a doctoral candidate with the Division of Resources and Environment at Curtin University. His PhD research is investigating the adaptive reuse of commercial buildings and he has published several research papers concerning sustainable buildings and adaptive reuse. He is a member of several working for the international research organization the Conseil Internationale du Batiment. He is also a corporate member of the Australian Institute of Building and Australian Institute of Project Management.

Thomas Fussell

Director and Chief Architect, Project Services, Department of Public Works Queensland

For the past fifteen years Thomas has been directly involved in the establishment of Project Services as a successful commercialised business within the Department of Public Works. This process has challenged the business to establish different relationships with its untied clients and to find more effective and more efficient ways to deliver its services. Thomas is focused on the greater use of advanced technologies to enable that improvement to be achieved. He is responsible for implementing the use of “virtual buildings” integrating the contribution of all of the disciplines into a single digital model to be used throughout the design, construction and operation of a building. The Off-site manufacture of components and assemblies has an important place in this new approach and has prompted his involvement in this project.

Willy Sher

Head of Building, School of Architecture and the Built Environment, The University of Newcastle

Willy Sher is Assistant Dean, Teaching and Learning in the Faculty of Engineering and Built Environment at Newcastle University. He is also Head of the Discipline of Building in the School of Architecture and Built Environment. Before coming to Australia he was Senior Lecturer in the Department of Building and Civil Engineering at Loughborough University (UK). He worked at the University of the Witwatersrand (South Africa) in the Department of Building and Quantity Surveying prior to this. He is a Fellow of the Australian Institute of Building and a Fellow of the Chartered Institute of Building.

Mark Vines

Program Director & Senior Lecturer, School of Property, Construction & Project Management, RMIT University

Mark is the Programs Director in the School of Property, Construction and Project Management and has been at RMIT for 16 years lecturing predominantly in the technology areas. Mark is also a registered Building Practitioner with over 20 years of housing experience, and is a member of the Australian Institute of Builders. Current research interests are focused in alternative wall systems for housing with ongoing industry collaboration.

Ron Wakefield

Professor and Head of School, School of Property, Construction & Project Management, RMIT University

Ron is currently Professor of Construction, and Head of the School of Property, Construction and Project Management at RMIT, Australia. He is also Program Director for Program C - Delivery and Management of Built Assets for the Cooperative Research Centre for Construction Innovation. His research and teaching is focussed on construction with particular emphasis on production systems, management of construction operations, use of information technology and whole of life performance of built assets. Prior to joining RMIT in 2005, Ron was the William E. Jamerson Professor of Building Construction in the Department of Building Construction, Virginia Tech, USA. He was Principal Investigator for the Industrializing the Construction Site project (Phases I, II, III, IV, V, Stage V extension) a multi million dollar research effort that lead to the Industrializing the Residential Construction Site series of monographs prepared for the Office of Policy Development and Research, US Department of Housing and Urban Development. Dr. Wakefield has over 20 years experience as an international researcher, consultant, and engineer in construction. Prior to joining Virginia Tech, Dr. Wakefield taught at The University of New South Wales, Sydney, Australia. He was a visiting Fellow at City University of Hong Kong in 1995.