DRIVERS, CONSTRAINTS AND THE FUTURE OF OFFSITE MANUFACTURE IN AUSTRALIA

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ABSTRACT

Much has been written on Off-site Manufacture (OSM) in construction, particularly regarding the perceived benefits and barriers to implementation. However, very little understanding of the state of OSM in the Australian construction industry exists. A ‘scoping study' has recently been undertaken to determine the ‘state-of-the-art’ of OSM in Australia. This involved several industry workshops, interviews and case studies across four major states of Australia. The study surveyed a range of suppliers across the construction supply-chain, incorporating the civil, commercial and housing segments of the market. This revealed that skills shortages and lack of adequate OSM knowledge are generally the greatest issues facing OSM in Australia. The drivers and constraints that emerged from the research were, in large measure, consistent with those found in the US and UK, although some Australian anomalies are evident, such as the geographical disparity of markets. A comparative analysis with similar studies in the UK and US is reported, illustrating both the drivers and constraints confronting the industry in Australia. OSM uptake into the future is however dependent on many factors, not least of which is a better understanding of the construction process and its associated costs.

Keywords: **offsite manufacture, Australia, drivers, constraints, United Kingdom, United States**

INTRODUCTION

Off-site Manufacture (OSM) has long been recognised, both in Australia and internationally, as offering numerous benefits to most parties in the construction process. It is further recognised as a key vehicle for driving process and efficiency improvements within developed construction industries. However, the use of OSM is not widespread, even though it may be intuitively appealing.

The perceived benefits and barriers of OSM are well documented, although little is known of the perceptions of OSM in Australia. Prior to 2006, no substantial research had been undertaken to investigate these views in Australia, although the industry had expressed interest, and predicted that OSM would increase in use over the next five to 15 years (Hampson & Brandon 2004).

To address this and provide a clearer agenda for developing OSM, a scoping study was undertaken. The CRC for Construction Innovation (CRC-CI) funded a project to determine the 'state-of-the-art' of OSM in Australia (Blismas, 2007). The project set out to understand the issues around the use of OSM, suggesting opportunities for future investment and research that would encourage its uptake. It covered civil, commercial and residential construction across four states in Australia (namely Victoria, Queensland, New South Wales and Western Australia).

This paper briefly discusses the results of the study, showing that skills and knowledge are key issues that will both drive and inhibit the growth of OSM use in Australia. It is contended that the understanding of OSM, both within the industry and research community, is immature and needs a paradigmal shift if it is to make a significant impact on construction industries across the developed world. Further, comparison is made with similar studies in the UK, highlighting the similarities and differences.

OFFSITE RESEARCH

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. Like the UK (e.g. Latham, 1994; Egan, 1998), Australian construction has been characterised as adversarial and inefficient; and in need of structural and cultural reform (Cole, 2003). Significant similarities exist between these two construction industries, not surprisingly given their common history. The reasons for the problems in the respective industries are complex, and require multiple, complimentary initiatives to effect significant 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), 're-branding' it broadly within the term 'Modern Methods of Construction' (Gibb, 1999).

Given the high profile offered to OSM in the UK, activities to encourage the adoption of OSM in that industry are 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 direct 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; PATH, 2002; Gibb & Isack, 2003; Goodier & Gibb, 2004a), uptake is limited. Goodier and Gibb (2004b) suggested that OSM accounted for approximately 2% of the £106.8bn UK construction sector in 2004. Pan, Gibb and Dainty (2007) likewise reported that the use of OSM in the UK housing sector was very low, with most top 100 housebuilders rarely using any OSM.

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* 2005). 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 'exemplar' and 'value-added' approaches.

A large effort has focussed on presenting (positive) examples 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, civils structures, airports through to modular office buildings. Most recently this 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). Examples and case studies, however serve no more purpose than to stimulate those not experienced in OSM to investigate the options on a project. The problem, as noted earlier, is an ability to then objectively assess the benefits offered by OSM.

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 value-added 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 comprehensive assessment of value than is commonly used in the industry, which is centred on simple cost comparisons. An analysis of the OSM assessment in six cases showed that most costing exercises simply take material, labour and transportation costs into account when comparing various options, often disregarding other indirect cost-related items such as site facilities, crane use and rectification of works (Blismas *et al*, 2006). Disregard of these cost items, together with issues such as health and safety, effects on management and process are largely to the detriment of OSM. A lack of understanding of the construction process and its associated costs is arguably the single most significant barrier to the use of OSM in construction. With this historically entrenched approach to costing, OSM will invariably appear more expensive than traditional methods.

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.

This project maps the Australian context against these previous studies, and serves as a platform for future work.

RESEARCH METHOD

The scoping study employed a variety of methods to collect data, which included industry workshops, case studies and interviews. Data gathering was deliberate and extensive across Australia, ensuring that a variety of perspectives were included in the study.

A series of three industry workshops was conducted in Melbourne, Perth and Brisbane to gather the views of a variety of stakeholders in the industry about the drivers and constraints of OSM use in Australia. Forty-five participants, ranging from clients, designers, constructors, suppliers and researchers were consulted. The programme for each workshop consisted of a series of presentations on various OSM systems and solutions encountered in the United Kingdom and United States, in both the commercial and residential sectors. An open discussion among delegates followed that documented the drivers, benefits, constraints and barriers to the adoption of OSM in Australia.

Seven case examples, spanning four states, of the use or manufacture of OSM products were also studied. The case studies involved site visits by the researchers, coupled with interviews of key persons in the relevant organisations and project teams.

LEVEL OF OSM IN AUSTRALIA

Ascertaining the value of OSM used in Australia would be a useful benchmark from which to begin a scoping study, however it is a very difficult exercise, as evidenced by the work of Goodier and Gibb (2004b). Part of the difficulty are the vague boundaries that exist between some traditional and OSM approaches, as well as data reporting between the construction and manufacturing industries. In the US for instance much of the OSM census data will be captured under manufacturing and not construction. Further, Australia has no industry peak body or association, apart from groups such as the National Precast Concrete Association, that represents offsite manufacturers as does the US or UK for instance. These vagaries are not easily overcome, and a number of assumptions are needed to make any reasonable estimate.

Gibb and Goodier (2004b) in trying to ascertain the size of the UK OSM market had to make several approximations and assumptions to derive their figures, and also found it ‘extremely difficult’ to obtain or calculate the true proportion of offsite which is imported or exported. In order to obtain meaningful industry volume data a combined top-down and bottom-up approach is required, which is both costly and time consuming – and may not produce accurate data. Nevertheless, in order to gain some indication of the types and volume of OSM occurring in Australia a comprehensive key word web search was initiated.

This soon showed that it was difficult to gain information about all the individual companies practicing OSM. This was related to a number of factors, including:

- Many companies, particularly the smaller ones, do not have websites;
- Many companies do not specifically advertise the fact that they make OSM items;
- Perceived uncertainties about what OSM actually is;
- No trade association providing a portal for publicising OSM;
- Some OSM items are of a transient nature – in that the manufacturing facility is set up and used for a particular construction project. Once finished this facility is removed.

Notwithstanding the obvious methodological shortcomings of simple web-searches, a comprehensive search produced a total of 50 manufacturers, whose information showed a direct involvement with OSM (this sample excluded roof truss manufacturers). The following table shows the number of manufacturers in that sample producing items from the different levels of OSM, and could suggest the current balance of manufacturing across all aspects of OSM within Australia. It should again be noted that this is in no way a representative sample of the industry, but merely a crude indicator.

Table 1: Activity in the different levels of OSM

Category	Typical items	No. of organisations
Non Volumetric pre-assembly	- Pre-cast concrete – beams, floors, wall panels, columns, pipes; - Steel fabrication; - Timber and steel wall panels	41
Volumetric pre-assembly	- Wet room modules	5
Modular building	- Homes; - Schools; - Shelters	8

NOTE: a number of manufacturers produce items across the three levels of OSM.

During interviews, respondents indicated that the two most commonly used OSM products are framing systems and cladding systems. Structural Insulated Panel Systems (SIPS), foundations and building services were related as the least commonly used. This concurs with the web-search findings above.

The following section presents the drivers and constraints arising from the workshops, case studies and interviews. These are tabulated and contrasted in the following section. Comment is made on how these findings compare to the UK literature.

DRIVERS AND CONSTRAINTS

The drivers and constraints of OSM as described by respondents were distilled into Table 2 below. These did not reveal anything particularly unique to Australia, although issues assumed different degrees of relevance to those in other countries. A comparative analysis of the results with similar UK/US research is provided in the next section, suggesting reasons for the unique features of the Australian industry.

Table 2: Drivers and constraints of OSM in the Australian construction industry.

Feature	Drivers	Constraints
Process & Programme	- Reduces construction time on-site, with consequent reduction in site disruptions and hazards; - Reduces time with related reduction in costs, such as reduced site costs and earlier income generation for clients; - Simplifies the construction process by reducing steps onsite.	- Longer lead times needed, especially for pre-planning and design; - Design process is based on the traditional mode and is unsuited to OSM; - Generally low levels 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.
Cost/Value/ Productivity	- Costs related to material and labour force pressures drive OSM, e.g., trade skills shortages such as bricklayers; inadequate supply of formwork; brick shortages etc.; - Allows for more efficient designs that reduce need for high safety margins and specifications; - Reduces 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.	- 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.
People & OHS	- Improves conditions for workers, controlled environments to protect workers from elements such e.g. rain, high temperatures etc.; - Reduces OHS risks onsite due to reduced time on-site; reduced likelihood due to lower hazard exposure; fewer trades and people on-site; - OHS risks can be better controlled in factory environment; - OSM gives sense of job security, not reliant on variable subcontractor work with a more stable workforce and better loyalty.	- Need for crane has specific safety risks associated with large loads; - Consequences of incident may be much higher due to large loads.

Feature	Drivers	Constraints
Skills & Knowledge	- Shortage of trade skills in remote areas and booming capitals is a major driver; - OSM attractive as it requires fewer trades; - Reduces skill shortage risk in ‘boom’ times, when it becomes difficult to find good tradesmen; - Systems that require lower skills may be favoured; - Can revitalise sectors in ‘traditional manufacturing’ areas that have lost their industries, benefits especially in areas of low skills where labour costs are low and improves local skills base.	- Limited expertise in the marketplace by designers and constructors of OSM and its processes, with design philosophy based on traditional methods that are unsuited to OSM; - Finer design skill and understanding is required to ensure interfaces are managed and designed, requiring higher onsite skill to deal with low tolerance OSM interfaces; - Education and training still focussed on current practices, not future ideas, with specific OSM skills limited; - May necessitate higher levels of IT literacy which is low in SMEs - Skills qualifications are not adequate or transferable, reliance is currently on supplier to train contractors to install correctly - General lack of guidance and information on OSM available in the market-place. Lack of single information source, rely on experience; - Particularly disadvantages SMEs.
Logistics & Site Operations	- Fewer trades on site aid coordination and reduce interfaces; - Ability to build and transport increasingly large components for delivery to (remote) areas without trade base, skills or facilities; - Enables better trade coordination.	- Production facility logistics and stock management difficult, especially with large concrete products, specifically limited access to and on site for manoeuvre - 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 etc.; - High mass of PC concrete products results in higher transport costs; - Low tolerances increase problems when fitting components onsite.
Quality	- Product testing allows for better control of safety factors/margins; - Can deliver better product quality, consistency, component life, reduced whole-life cost and defects through QA in controlled factory environment; - Design can be refined in manufacture to improve quality, and enables new/different materials and processes to be used	None recorded

Feature	Drivers	Constraints
Environmental sustainability	- Building and especially on-site waste (up to 40% of landfill) can be reduced by OSM; - Energy efficiency requirements 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 incorporate sustainable solutions.	- Energy ratings (in Australia) not affected by OSM as measured at the design stage on the building rather than the construction process, or completed unit.
Regulatory	None recorded	- 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; - Inadequate Codes for OSM varieties, e.g. addresses tilt-up but not other pre-cast products; - Inconsistency between local and shire legislation and interpretations.
Industry & Market Culture	None recorded	- Unionised labour market can limit flexibility OSM can give; - Client's desire for particular structures or traditional finishes may inhibit OSM, design options seen to be too limited; - Negative stigma from failures or perceived low-quality products; - Difficulty obtaining finance from institutions more familiar with traditional approaches.
Supply-chain & Procurement	None recorded	- Capacity to supply OSM products is limited (severe in places of Australia 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.

COMPARATIVE ANALYSIS

Given the results of table 2, a brief analysis of the drivers and constraints is made for each feature, whilst also relating these to the literature to assess their relevance within the Australian context.

Process & Programme	There appears to be a low appreciation of the delivery speeds which OSM can offer, which is recognised as a major benefit of offsite in US and UK studies. Speed of construction is one of the key benefits of OSM and needs to be understood. By contrast the constraints seem to be well understood and mirror closely those put forward within the literature. Industry conditions are generally similar between Australia, UK and parts of the US. 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. There is a need to learn from other industry's systems, such as manufacture – 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 - More accurate production Similarly, information and document distribution and management protocols are required in a high IT environment. Storage and ownership of digital information also needs to be addressed within this protocol.
Cost/Value/ Productivity	There appears to be a lack of awareness of the possible cost savings over the whole-life of OSM products. Whole-life cost needs to be emphasised with understanding of value rather than purely direct material/labour costs. Much work in the UK has been done to try and demonstrate the real value of OSM. Interestingly fewer cost/value constraints were identified in the Australian study, although implications are that they are similar to other countries. A system or method is required to objectively ascertain the benefits of OSM. Similarly, perceptions that design fees are more expensive, need to be understood as being potentially lower as they are 'written-off' within standard products.
People & OHS	There was a markedly higher emphasis by Australian respondents to labour working conditions, perhaps due to the IR climate, which can vary between States, and certainly differs to that of the UK and US. OSM can provide better working conditions for workers, and is an area for potential promotion. Almost no constraints were identified either in the literature or the Australian workshops, suggesting this to be a positive driver for OSM. However resistance to OSM is expected where trades are threatened and more control of the workforce is possible.

Skills & Knowledge	The acute labour skills shortage seems to be more pronounced in the limited Australian environment. Importation of ‘cheaper’ labour with new IR laws has been met cautiously due to resistance from Unions .The issue however is certainly becoming a prominent driver in the US and UK. There appears to be a high degree of correlation between the literature and Australian observations. There is little industrial knowledge on OSM in the Australian construction industry, unlike the UK. Initiatives to change this include: funding to attend conferences/meetings; improved research incentives to stimulate local innovation and start-ups; paradigm shift towards manufacture; 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 sources; portal to disseminate international trends, products and processes; market research needed to ascertain opportunities.
Logistics & Site Operations	The Australian industry appears to appreciate fewer benefits due to logistics and site operation, perhaps due to low levels of OSM use and exposure. While the constraints appeared greater than those reported in the literature. Transport costs due to vast distances between disparate capitals. Other ‘unique’ constraints include crane driver vulnerability in some States due to unionisation.
Quality	Interestingly no quality constraints were identified in the Australian workshops which correlate very closely with the literature. This becomes a very important driver in a skills-deficient industry.
Environmental sustainability	Although the literature was not as explicit, its drivers encompass those identified for Australia. The sharp increase in environmental awareness in recent years may account for the apparent lack of this factor in the literature. It is however very prevalent, with OSM claiming to be able to produce much higher performance products than traditional systems.
Regulatory	Australian regulatory fragmentation appears to pose similar challenges to those in the UK and US. These constraints are expected given the low level of OSM use. Regulatory change will need to develop simultaneously with increasing OSM use.
Industry & Market Culture	‘The whole industry is conservative’, with resistance to change by contractors, suppliers and professions. The historical negative sentiment against OSM is common to both Australia and the UK. Massive post-war and 1960-70’s social housing projects have given OSM dwellings a poor reputation. Although the client profile has changed since then, some of the sentiment remains. Remote housing in Australia using simple pre-fabricated houses added to the reputation that OSM produces only ‘low-cost’ products.
Supply-chain & Procurement	The Australian market appears to have emphasised constraints in the OSM supply-chain, perhaps due to the relatively small size of the market coupled with the massive physical disparity of production centres. The far larger US and European markets mitigate against some of these concerns, although the OSM market is still, in relative terms, small.

CONCLUSIONS

The drivers and constraints of OSM within the Australian construction industry are substantially the same as those identified in the UK and the US housing market. The leading driver of OSM is undoubtedly the increasing shortage of skilled trades and labour for the industry. The resources and property ‘booms’ across Australia over the past five years have exacerbated the shortages and brought into focus the need to explore alternate forms of procurement. However there is no direct substitute for trade labour in OSM. The move to OSM essentially requires an entire change to the process of project conception, design and production.

In summary, OSM was also seen to: reduce construction time; simplify the construction processes; provide higher quality and better control; provide high levels of consistency; 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. Whilst these drivers are all attractive, they are not guaranteed with OSM unless a fundamental process change is made. Many of the constraints attest to the inertia of the industry, and the immense difficulty involved in change.

The constraints of OSM were seen to: 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.

The constraints are similar to those identified in the literature and are reflective of the industry’s traditional fragmented structure. The constraints can be abstracted to process change, high capital expenditure, supply-chain restrictions and regulatory restrictions. Process change, and the attitudes of the trades and professions, expressed as a lack of OSM knowledge, may be the greatest constraints. Attitudes and ‘ways of working’ are difficult to transform and take a ‘generation’ to change. A better understanding of the work involved and the precise labour expended is also needed, and is likely to show OSM as a more competitive alternative.

OSM adoption in Australia, as in other countries, requires fundamental structural changes to the industry. OSM changes the way people in the building industry work, both in terms of the process and product. The real advantages of OSM can only be realised through a thorough understanding of the principles underpinning manufacturing, whilst also appreciating the constraints and pitfalls that come with a fragmented construction industry. Whilst this scoping study has not revealed any new view to OSM research in construction, it has formed a base for further work within Australia. Indeed several new initiatives have begun, within housing particularly, demonstrating that the drivers are strong enough to motivate sectors of the industry to invest resources to overcome the constraints.

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